

U.S. Environmental
Protection Agency, Region 5

PILOT STUDY REPORT

Revision 2

Tower Standard LUST Site
Lac du Flambeau Indian Reservation
Lac du Flambeau, Wisconsin

EPA Contract No. EP-W-12-009
Task Order 68HERH20F0243

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TABLE OF CONTENTS

<u>SECTION</u>	<u>PAGE</u>
ACRONYMS AND ABBREVIATIONS	iii
1.0 INTRODUCTION	1
1.1 Objectives	1
2.0 SITE ACTIVITIES	3
2.1 Subcontractor Support	3
2.2 Mobilization and Site Survey	4
2.3 Well and Vapor Point Installation	4
2.4 Well Development	7
2.5 Groundwater Sampling	7
2.6 Investigation-Derived Waste	9
3.0 FINDINGS	11
3.1 Groundwater Analytical Results	11
4.0 CONCLUSIONS	15
5.0 REFERENCES	17

TABLES

Table 1	November 2020 Groundwater Analytical Results
Table 2	Pilot Study Vapor Analytical Results

FIGURES

Figure 1	Location Map
Figure 2	Site Map
Figure 3	Pilot Test Work Area Map
Figure 3	November 2020 Groundwater Analytical Data

APPENDICES

Appendix A	S&W Draft Pilot Test Report
Appendix B	Photograph Log
Appendix C	Field Notes
Appendix D	Survey Data
Appendix E	Soil Boring Logs and Soil Core Photographs
Appendix F	Well Construction Diagrams
Appendix G	Well Development Forms
Appendix H	Groundwater Sampling Forms
Appendix I	Investigation-Derived Waste Documentation
Appendix J	Laboratory Analytical Reports
Appendix K	Data Review Memorandum

ACRONYMS AND ABBREVIATIONS

AS	air sparge
bgs	below the ground surface
Bristol	Bristol Environmental Remediation Services, LLC
Cascade	Cascade Environmental Remediation Services, LLC
EDB	ethylene dibromide [1,2-dibromoethane]
EPA	U.S. Environmental Protection Agency
HDPE	high-density polyethylene
IDW	investigation-derived waste
LDF	Lac du Flambeau
LNAPL	light non-aqueous phase liquid
LOQ	limit of quantitation
LUST	leaking underground storage tanks
Mi-Tech	Mi-Tech Services, Inc.
MCL	maximum contaminant level
Pace	Pace Analytical Services, Inc.
PID	photoionization detector
PVC	polyvinyl chloride
S&W	Shannon & Wilson, Inc.
SGS	SGS Environmental Contracting, LLC
SME	Subject Matter Expert
SVE	soil vapor extraction
SW	EPA Solid Waste Test Method
TO	Task Order
VOC	volatile organic compound

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1.0 INTRODUCTION

The U.S. Environmental Protection Agency (EPA) retained Bristol Environmental Remediation Services, LLC (Bristol), to prepare this summary report for an air sparge/soil vapor extraction (AS/SVE) pilot test performed at the Sundberg property adjacent to the Tower Standard leaking underground storage tank (LUST) site located on the Lac du Flambeau (LDF) Indian Reservation in Lac Du Flambeau, Wisconsin (Figures 1 and 2).

The LUST site is referred to as the Tower Standard Service Gas Station and Auto Repair/Haskell Lake Contamination Site by the Lac du Flambeau Band of Lake Superior Chippewa Indians. The EPA assigned this project to Bristol under Contract No. EP-W-12-009, Task Order (TO) 68HERH20F0243.

The AS/SVE pilot test was performed in accordance with the *Work Plan and Site-Specific QAPP* (Bristol, 2020b), *Site Safety and Health Plan* (Bristol, 2020a), and *Quality Assurance Project Plan* (Bristol, 2019), except where noted.

1.1 OBJECTIVES

Objectives of this field work included evaluating the efficacy of AS/SVE as a potential approach to remediate contaminants remaining at the LUST site. A secondary objective was to perform a groundwater sampling event for wells located on the Sundberg Property.

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2.0 SITE ACTIVITIES

Bristol initially mobilized to the Tower Standard site on November 9, 2020. Bristol installed monitoring wells, remediation wells, and soil vapor sampling points from November 9 through 16, 2020. Bristol then performed a round of groundwater sampling immediately prior to initiation of the AS/SVE pilot test on November 18, 2020. The pilot test was completed on November 20, 2020 and all personnel demobilized.

Well installation, well development, and groundwater sampling site activities are described below. The AS/SVE pilot test itself (including collection of air samples and evaluation of air data) is described in a report included as Appendix A.

Field activities are documented in site photographs (Appendix B) and field notes (Appendix C).

2.1 SUBCONTRACTOR SUPPORT

Bristol worked with the following subcontractors to complete site activities:

- Shannon & Wilson, Inc. (S&W) of Madison, Wisconsin provided the trailer-mounted AS-SVE system and technical staff to perform the AS/SVE pilot test. S&W also authored the Pilot Test Report included as Appendix A.
- Mi-Tech Services, Inc. (Mi-Tech) of Weston, Wisconsin provided professional land surveying support.
- Cascade Environmental Remediation Services, LLC (Cascade) provided drilling support.
- Pace Analytical (Pace) of Green Bay, Wisconsin provided analytical services.
- SGS Environmental Contracting, LLC (SGS) of Merrill, Wisconsin provided investigation-derived waste (IDW) transportation and disposal support.

Bristol provided contractor oversight, logged soil borings, performed field screening, and collected groundwater and vapor samples.

2.2 MOBILIZATION AND SITE SURVEY

Bristol geologist Scott Ruth and EPA subject matter expert (SME) Bob Egan mobilized to the Tower Standard site on the morning of November 9, 2020. Bristol and EPA personnel marked all proposed drilling locations with ground-marking paint and survey whisksers.

A Mi-Tech surveyor arrived at the site at mid-morning and marked the property line between the Sundberg parcel and the Tower Standard site property (Figure 3). The surveyor also surveyed the planned drilling locations in addition to existing monitoring wells MW-20, MW-20D, MW-21M, and MW-21D. The surveyor recorded northing and easting (but not elevation) for these points. Locations may have been adjusted slightly immediately prior to drilling to provide sufficient room for safe operations. Survey data is included as Appendix D.

Additional personnel, including a representative from the LDF Tribe, an environmental scientist from Weston Solutions contracted by the LDF Tribe to perform soil sampling, additional EPA personnel, and the drillers, arrived over the course of the day. The drillers, who didn't arrive until mid-afternoon, were only able to unload materials and did not begin drilling until the following day.

2.3 WELL AND VAPOR POINT INSTALLATION

Drilling activities began on the morning of November 10, 2020. Cascade advanced all soil borings for monitoring wells, pilot test system wells, and vapor monitoring points using a Boart Longyear LS250 MiniSonic rig. Sonic drilling technology was selected for the project due to difficult drilling conditions encountered in the deep borings at the site during previous investigations; including cobbles and/or boulders at depth near the bedrock interface that make the advancement of hollow-stem augers challenging or impossible. Cascade advanced the soil borings by sonically advancing a 10-foot-long, 3.75-inch diameter inner core barrel into the ground surface, followed by a 6-inch

diameter outer casing over the core barrel. After advancing the outer casing to match the depth of the inner core barrel, the core was retrieved and brought to the surface for examination. The process was repeated until the desired total depth of each soil boring was reached.

Cascade collected the core into plastic bags and transferred the core to the Bristol geologist for logging and field screening. The Bristol geologist cut the bags open and logged the soil borings, recording such lithologic information as grain size, color, qualitative moisture content, and other details such as petroleum odor. Bristol also documented all retrieved soil cores with photographs. Soil boring logs and core photographs are included as Appendix E.

The Bristol geologist also performed field soil screening of the recovered core, including in situ screening of soil core for volatile organic compounds (VOCs) using a photoionization detector (PID). Bristol also screened visibly highly contaminated intervals of soil core for presence of light non-aqueous phase liquids (LNAPLs) using a variety of methods, including visual inspection, shake tests, and examination of core under an ultraviolet light in a specialized viewing cabinet. Shake tests were performed by placing soil and water inside a 4-ounce, clear glass sample jar, shaking the jar vigorously, then examining the water surface for the presence of sheen. No evidence of LNAPLs was noted through these tests.

Once the desired depth of a soil boring was reached, Cascade installed a well or vapor point in the soil boring as directed by Bristol. Well construction diagrams are included as Appendix F. Installations can be divided into six categories: shallow monitoring wells, deep monitoring wells, shallow AS wells, deep AS wells, SVE wells, and vapor monitoring points.

- The shallow monitoring wells (MW-23S and MW-24S) were completed to depths of approximately 15 feet below the ground surface (bgs) with 2-inch diameter

schedule 40 polyvinyl chloride (PVC) casing. These wells were screened across the water table (approximately 8 feet bgs) with 10-foot sections of 0.010-inch slotted screen from approximately 5 to 15 feet bgs. The annulus of the borehole was filled with 10-20 silica sand from the bottom of the hole to approximately two feet above the screen, a 2-foot thick layer of hydrated 3/8-inch bentonite chips above the sand, and bentonite grout to just below the ground surface. The wells were completed with flush mount monuments with locking caps set in the top of the PVC casing.

- The deep monitoring wells (MW-23D and MW-24D) were completed to depths of approximately 45-50 feet bgs with 2-inch diameter schedule 40 PVC casing. These wells were screened below the water with 10-foot sections of 0.010-inch slotted screen (from 40-50 feet bgs at MW-23D and 35-45 feet bgs at MW-24D). The annulus of the borehole was filled with 10-20 silica sand from the bottom of the hole to approximately two feet above the screen, a 2-foot thick layer of hydrated 3/8-inch bentonite chips above the sand, and bentonite grout to just below the ground surface. The wells were completed with flush mount monuments with locking caps set in the top of the PVC casing.
- The shallow AS wells (AS-1, AS-3, and AS-5) were completed to depths of approximately 22 feet bgs with 2-inch diameter stainless steel casing. These wells were screened with 2-foot sections of 0.010-inch slotted screen from approximately 20 to 22 feet bgs. The annulus of the borehole was filled with 10-20 silica sand from the bottom of the hole to approximately two feet above the screen, a 2-foot thick layer of hydrated 3/8-inch bentonite chips above the sand, and bentonite grout to just below the ground surface. The wells were completed with flush mount monuments with locking caps set in the top of the steel casing.
- The deep AS wells (AS-2, AS-4, and AS-6) were each completed to depths of approximately 57 feet bgs with 2-inch diameter stainless steel casing. These wells were screened with 2-foot sections of 0.010-inch slotted screen from approximately 55 to 57 feet bgs. The annulus of the borehole was filled with 10-20 silica sand from the bottom of the hole to approximately two feet above the screen, a 2-foot thick layer of hydrated 3/8-inch bentonite chips above the sand, and bentonite grout to just below the ground surface. The wells were completed with flush mount monuments with locking caps set in the top of the steel casing.
- The SVE wells (SVE-1 through SVE-6) were completed to depths of approximately 13 feet bgs with 4-inch diameter schedule 40 PVC casing. These wells were screened across the water table (approximately 8 feet bgs) with 10-foot sections of 0.010-inch slotted screen from approximately 3 to 14 feet bgs. The annulus of the borehole was filled with 10-20 silica sand from the bottom of the hole to

approximately 6 inches above the screen, an 18-inch thick layer of hydrated 3/8-inch bentonite chips above the sand, and bentonite grout to just below the ground surface. The wells were completed with flush mount monuments with locking caps set in the top of the PVC casing.

- The vapor points (VP-1 through VP-3) were completed to depths of approximately 5 feet bgs. The open boreholes were filled with 10-20 silica sand to a depth of approximately 2.8 feet bgs, with a 6-inch stainless steel vapor point set from approximately 3.5 to 4 feet bgs and attached to high-density polythelene (HDPE) tubing running to the surface. Six inches of granular bentonite was placed above the sand and carefully hydrated, followed by bentonite grout to just below the ground surface. The vapor points were completed with flush mount monuments and the exposed HDPE tubing was coiled up inside the well vault.

Well installations were completed on November 16, 2020. Cascade containerized all soil cuttings into 55-gallon drums and consolidated the drums on site for later transport and disposal.

2.4 WELL DEVELOPMENT

Cascade developed the monitoring wells and air sparge wells by pumping with a submersible pump, periodically surging the well screen by moving the pump up and down through the screened interval. During development of the monitoring wells, Bristol monitored water quality parameters (turbidity, pH, temperature, dissolved oxygen, and specific conductance) with a YSI ProDSS water quality meter. During development of the sparge wells, Bristol did not collect water quality measurements, but made qualitative observations of turbidity. All development water was containerized into 55-gallon drums for later transport and disposal.

Well development logs are included as Appendix G.

2.5 GROUNDWATER SAMPLING

On November 16, 2020 Bristol began collecting groundwater samples. On November 17, S&W personnel arrived on-site and began assisting with the groundwater sampling effort. Bristol (with the assistance of S&W) collected groundwater samples from the four newly

installed monitoring wells (MW-23S, MW-23D, MW-24S, and MW-24D) as well as four existing monitoring wells (MW-20, MW-20D, MW-21M, and MW-21D) located on the Sundberg Property.

Before collecting a groundwater sample, Bristol measured the depth to groundwater at each well with an interface probe, to an accuracy of 0.01-foot. An interface probe is capable of detecting the presence of LNAPL in a monitoring well. Bristol also screened for the presence of LNAPL using a clear bailer to capture the top of the water column and bring to the surface for observation—none of the eight wells were found to contain LNAPL.

Bristol then used submersible bladder pumps (including a QED Sample Pro and a QED Well Wizard) to purge and sample each well using low-flow sampling methodology. During purging, Bristol directed groundwater through a flow-through cell and measured water quality parameters (including pH, dissolved oxygen, specific conductance, temperature, turbidity, and oxygen reduction potential) using a YSI ProDSS multi-parameter, water quality instrument. Once parameters stabilized, Bristol disconnected the flow-through cell and began collecting groundwater samples by directing the flow into laboratory-supplied sample containers.

Sampling personnel donned new, clean nitrile gloves prior to sample collection. Bristol used disposable, bonded polyethylene tubing with the pump and replaced the tubing and bladders between each well. Bristol decontaminated the bladder pump itself between each well with an Alconox and water solution and a distilled water rinse.

Bristol consolidated all purged water into 55-gallon drums for later transport and disposal.

Groundwater low flow purging forms for each well are included as Appendix H.

Bristol submitted groundwater samples to Pace in Green Bay, Wisconsin, for laboratory analysis of VOCs by EPA solid waste method (SW) 8260, 1,2-dibromoethane (EDB) by

SW8011, and dissolved metals (including arsenic, barium, cadmium, chromium, iron, lead, manganese, mercury, selenium, and silver) by SW6020. Bristol submitted a total of eight primary samples, one field duplicate, one matrix spike/matrix spike duplicate pair, one equipment rinsate blank, and one trip blank for analysis.

2.6 INVESTIGATION-DERIVED WASTE

IDW consisted of soil cuttings from well installation, purge water from well development and groundwater sampling, and disposable, personal protective equipment and sampling supplies (sample tubing, nitrile gloves, etc.). Bristol and SGS characterized IDW using analytical data from previous investigations to minimize delays in getting IDW removed from the site.

SGS mobilized to the site on December 4, 2020 and picked up ten drums of soil cuttings and 14 drums of purge/development water. While on site, SGS also cleaned up some concrete debris mess that had been left by Cascade and later noted by representatives of the LDF tribe. SGS transported the soil drums to the Lincoln County Landfill in Merrill, Wisconsin and the water drums to Chief Industrial Services in Winneconne, Wisconsin for proper disposal.

Documentation of IDW disposal is included as Appendix I.

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3.0 FINDINGS

Findings of the AS/SVE pilot study are discussed in Appendix A.

3.1 GROUNDWATER ANALYTICAL RESULTS

Analytical results for groundwater samples are presented on Table 1, and complete laboratory analytical reports are included in Appendix J. Select analytical results (including from previous sampling events) are presented on Figure 4. A data review memo is included as Appendix K.

Analytical results were compared to Groundwater Cleanup Standards from the LDF Tribe's *Hazardous Substances Control Code* (LDF Tribe, 2008) as well as EPA Maximum Contaminant Levels (MCLs) (EPA, 1974).

- EDB was detected in groundwater samples collected from two of eight monitoring wells (MW-20 and MW-20D) at concentrations up to 24.9 µg/L, exceeding the LDF standard of 0.05 µg/L (no EPA MCL established). All non-detect results had limits of quantitation (LOQs) that were lower than the LDF standard.
- Benzene was detected in groundwater samples collected from six of eight monitoring wells, at concentrations ranging from an estimated 13.6 µg/L (MW-23S) to 4,230 µg/L (MW-20D). All detected results exceeded the LDF standard and EPA MCL of 5 µg/L; all non-detect results had LOQs that were lower than 5 µg/L.
- Ethylbenzene was detected in groundwater samples collected from seven of eight monitoring wells. Samples collected from MW-20, MW-20D, MW-21M and MW-23S exceeded the LDF standard and EPA MCL of 700 µg/L, with a maximum concentration of 4,310 µg/L in the sample collected from MW-20. All non-detect results had LOQs that were lower than 700 µg/L.
- Naphthalene was detected in groundwater samples collected from six of eight monitoring wells. Samples collected from MW-20, MW-20D, MW-21M, and MW-23S exceeded the LDF standard of 40 µg/L (no EPA MCL established), with a maximum concentration of 702 µg/L in the sample collected from MW-20. All non-detect results had LOQs that were lower than the LDF standard.
- Toluene was detected in groundwater samples collected from seven of eight monitoring wells. Samples collected from MW-20 and MW-20D exceeded the LDF standard and EPA MCL of 1,000 µg/L, with a maximum concentration of

29,900 µg/L in the sample collected from MW-20D. All non-detect results had LOQs that were lower than 1,000 µg/L.

- Xylenes (total) were detected in samples collected from all eight monitoring wells. Samples collected from MW-20, MW-20D, and MW-23S exceeded the LDF standard and EPA MCL of 10,000 µg/L, with a maximum concentration of 21,400 µg/L in the sample collected from MW-20.

At the MW-20 well pair, concentrations exceed LDF standards and EPA MCLs in samples collected from both the deep (MW-20D) and shallow (MW-20) monitoring wells. EDB, benzene, and toluene concentrations were higher in the deep sample, while ethylbenzene, naphthalene, and xylene concentrations were higher in the shallow sample.

At the MW-21 well pair, concentrations were higher in the sample collected from the shallower well (MW-21M). While benzene exceeded the LDF standard and EPA MCL in samples collected from both wells, ethylbenzene and naphthalene only exceeded limits in the sample collected from MW-21M.

At the MW-23 well pair, concentrations were higher in the sample collected from the shallower well (MW-23S). Benzene, ethylbenzene, naphthalene, and xylenes exceeded the LDF standard or the EPA MCL at MW-23S, while the sample collected from MW-23D was below limits for all analytes.

Conversely, at the MW-24 well pair, concentrations were higher in the sample collected from the deeper well (MW-24D). Benzene was the only analyte that exceeded either the LDF standard or the EPA MCL at MW-24D, while the sample collected from MW-24S was below limits for all analytes.

For existing wells that have been sampled on multiple occasions, in general a decreasing trend in contaminant concentrations over time can be observed (Figure 4). However, more data points are necessary to confirm this trend, as the five previous monitoring events were all performed in a nine-month period between November 2015 and August 2016.

3.2 VAPOR ANALYTICAL RESULTS

Analytical results for vapor samples are presented on Table 2, and complete laboratory analytical reports are included in Appendix J. A data review memo is included as Appendix K. Analysis of vapor sample results as relevant to evaluation of the AS/SVE pilot study are discussed in Appendix A.

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4.0 CONCLUSIONS

Results of the pilot test indicate that AS/SVE is a viable remedial technology for the Tower Standard LUST Site, and that operation of a full-scale AS/SVE system could result in a significant mass reduction of gasoline-range VOCs in the groundwater and subsurface soil. Sparged air was found to be mobile in the subsurface and SVE wells were found to be effective at capturing sparged air. The radius of influence for SVE wells was calculated to be between 44 and 65 feet. Mounding of the shallow water table during AS operations was observed but found to be minimal, and water levels were found to recover quickly to baseline conditions.

More detailed discussion of the conclusions of the AS/SVE pilot test are presented in the Pilot Test Report included as Appendix A. Upon approval of the Pilot Study Report, work could proceed immediately on design of a full-scale AS/SVE system.

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5.0 REFERENCES

- Bristol Environmental Remediation Services, LLC (Bristol). (2019). *Quality Assurance Project Plan* (Revision 0). LUST Sites in Indian Country EPA Region 5.
- Bristol. (2020a). *Health and Safety Plan* (Revision 2). Tower Standard LUST Site, Lac du Flambeau Indian Reservation, Lac du Flambeau, Wisconsin.
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- U.S. Environmental Protection Agency (EPA). (1974). Safe Drinking Water Act. 42 United States Code 6A.
- Lac du Flambeau (LDF) Tribe. (2008). *Tribal Code, Section 2, Chapter 200, Hazardous Substance Control Code*. Website:
<https://www.ldftribe.com/Court%20Ordinances.php>

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TABLES

Table 1 November 2020 Groundwater Analytical Results

Sample ID					MW-20	MW-20D	MW-21D	MW-21M	MW-23D	MW-23S	MW-24D	MW-25D	MW-24S
Monitoring Well ID					MW-20	MW-20D	MW-21D	MW-21M	MW-23D	MW-23S	MW-24D		MW-24S
Collection Date/Time					11/17/2020 12:40	11/17/2020 11:40	11/17/2020 13:05	11/17/2020 14:45	11/17/2020 9:45	11/17/2020 11:45	11/16/2020 13:45	11/16/2020 14:00	11/16/2020 15:45
Lab Sample ID					10539600007	10539600008	10539600010	10539600012	10539600009	10539600011	10539600003	10539600001	10539600002
Matrix					Water	Water	Water	Water	Water	Water	Water	Water	Water
Quality Control Sample Type					Primary	Primary	Primary	Primary	Primary	Primary	Primary	Duplicate of MW-24D	Primary
Analytical Method	Analyte	Units	LDF Groundwater Cleanup Standards ¹	EPA MCLs ²	Analytical Results								
EPA 6020	Arsenic, Dissolved	µg/L	10	10	2.4	5.5	ND (1)	1.1	ND (1)	0.79 J	0.42 J	1.2	1.2
EPA 6020	Barium, Dissolved	µg/L	2,000	2,000	36.5	27.8	164	66.4	332	18.2	242	241	29.5
EPA 6020	Cadmium, Dissolved	µg/L	5	5	ND (1)	3.3	ND (1)	ND (1)	ND (1)	ND (1)	0.27 J	0.95 J	ND (1)
EPA 6020	Chromium, Dissolved	µg/L	50	100	6.3	7.6	1	3.6	1	1.8	2	2.1	4.4
EPA 6020	Iron, Dissolved	µg/L	NE	NE	16000	6870	4570	19800	ND (250)	6930	6050	3750	7090
EPA 6020	Lead, Dissolved	µg/L	15	NE	5.7	11.5	0.31 J	0.33 J	ND (1)	1.4	0.6 J	1.1	2.1
EPA 6020	Manganese, Dissolved	µg/L	NE	NE	10700	7060	1030	2820	836	4240	1200	1060	920
EPA 6020	Mercury, Dissolved	µg/L	2	2	ND (0.31)	ND (0.31)	ND (0.31)	ND (0.31)	ND (0.31)	ND (0.31)	ND (0.31)	ND (0.31)	ND (0.31)
EPA 6020	Selenium, Dissolved	µg/L	50	50	1.2	6.3	ND (1.1)	0.51 J	ND (1.1)	ND (1.1)	0.4 J	1.2	0.32 J
EPA 6020	Silver, Dissolved	µg/L	50	NE	ND (0.5)	1.5	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	ND (0.5)	0.5 J	ND (0.5)
EPA 8011	1,2-Dibromoethane (EDB)	µg/L	0.05	NE	2.21	24.9	ND (0.0179)	ND (0.0179)	ND (0.0179)	ND (0.0179)	ND (0.0179)	ND (0.0179)	ND (0.0179)
EPA 8260	1,1,1,2-Tetrachloroethane	µg/L	70	NE	ND (125)	ND (250)	ND (1)	ND (40)	ND (1)	ND (20)	ND (10)	ND (5)	ND (1)
EPA 8260	1,1,1-Trichloroethane	µg/L	200	NE	ND (125)	ND (250)	ND (1)	ND (40)	ND (1)	ND (20)	ND (10)	ND (5)	ND (1)
EPA 8260	1,1,2,2-Tetrachloroethane	µg/L	0.2	NE	ND (125)	ND (250)	ND (1)	ND (40)	ND (1)	ND (20)	ND (10)	ND (5)	ND (1)
EPA 8260	1,1,2-Trichloroethane	µg/L	5	NE	ND (625)	ND (1250)	ND (5)	ND (200)	ND (5)	ND (100)	ND (50)	ND (25)	ND (5)
EPA 8260	1,1-Dichloroethane	µg/L	850	NE	ND (125)	ND (250)	ND (1)	ND (40)	ND (1)	ND (20)	ND (10)	ND (5)	ND (1)
EPA 8260	1,1-Dichloroethene	µg/L	7	NE	ND (125)	ND (250)	ND (1)	ND (40)	ND (1)	ND (20)	ND (10)	ND (5)	ND (1)
EPA 8260	1,1-Dichloropropene	µg/L	NE	NE	ND (225)	ND (450)	ND (1.8)	ND (72)	ND (1.8)	ND (36)	ND (18)	ND (9)	ND (1.8)
EPA 8260	1,2,3-Trichlorobenzene	µg/L	NE	NE	ND (921)	ND (1840)	ND (7.4)	ND (295)	ND (7.4)	ND (147)	ND (73.7)	ND (36.8)	ND (7.4)
EPA 8260	1,2,3-Trichloropropane	µg/L	60	NE	ND (625)	ND (1250)	ND (5)	ND (200)	ND (5)	ND (100)	ND (50)	ND (25)	ND (5)
EPA 8260	1,2,4-Trichlorobenzene	µg/L	70	NE	ND (625)	ND (1250)	ND (5)	ND (200)	ND (5)	ND (100)	ND (50)	ND (25)	ND (5)
EPA 8260	1,2,4-Trimethylbenzene	µg/L	NE	NE	2890	1520	3.2	678	ND (2.8)	2200	172	167	30.5
EPA 8260	1,2-Dibromo-3-chloropropane	µg/L	0.2	NE	ND (735)	ND (1470)	ND (5.9)	ND (235)	ND (5.9)	ND (118)	ND (58.8)	ND (29.4)	ND (5.9)
EPA 8260	1,2-Dichlorobenzene	µg/L	600	NE	ND (294)	ND (588)	ND (2.4)	ND (94)	ND (2.4)	ND (47)	ND (23.5)	ND (11.8)	ND (2.4)
EPA 8260	1,2-Dichloroethane	µg/L	5	NE	ND (125)	ND (250)	ND (1)	ND (40)	ND (1)	ND (20)	ND (10)	ND (5)	ND (1)
EPA 8260	1,2-Dichloropropane	µg/L	5	NE	ND (125)	ND (250)	ND (1)	ND (40)	ND (1)	ND (20)	ND (10)	ND (5)	ND (1)
EPA 8260	1,3,5-Trimethylbenzene	µg/L	NE	NE	717	374 J	1.2 J	162	ND (2.9)	505	27.6 J	25.6	17.4
EPA 8260	1,3-Dichlorobenzene	µg/L	1,250	NE	ND (262)	ND (523)	ND (2.1)	ND (83.7)	ND (2.1)	ND (41.9)	ND (20.9)	ND (10.5)	ND (2.1)
EPA 8260	1,3-Dichloropropane	µg/L	NE	NE	ND (344)	ND (688)	ND (2.8)	ND (110)	ND (2.8)	ND (55.1)	ND (27.5)	ND (13.8)	ND (2.8)
EPA 8260	1,4-Dichlorobenzene	µg/L	75	NE	ND (393)	ND (786)	ND (3.1)	ND (126)	ND (3.1)	ND (62.9)	ND (31.5)	ND (15.7)	ND (3.1)
EPA 8260	2,2-Dichloropropane	µg/L	NE	NE	ND (944)	ND (1890)	ND (7.6)	ND (302)	ND (7.6)	ND (151)	ND (75.5)	ND (37.8)	ND (7.6)
EPA 8260	2-Chlorotoluene	µg/L	NE	NE	ND (625)	ND (1250)	ND (5)	ND (200)	ND (5)	ND (100)	ND (50)	ND (25)	ND (5)
EPA 8260	4-Chlorotoluene	µg/L	NE	NE	ND (315)	ND (630)	ND (2.5)	ND (101)	ND (2.5)	ND (50.4)	ND (25.2)	ND (12.6)	ND (2.5)
EPA 8260	Benzene	µg/L	5	5	1070	4230	34.5	1980	ND (1)	13.6 J	441	431	ND (1)
EPA 8260	Bromobenzene	µg/L	NE	NE	ND (125)	ND (250)	ND (1)	ND (40)	ND (1)	ND (20)	ND (10)	ND (5)	ND (1)
EPA 8260	Bromochloromethane	µg/L	NE	NE	ND (625)	ND (1250)	ND (5)	ND (200)	ND (5)	ND (100)	ND (50)	ND (25)	ND (5)
EPA 8260	Bromodichloromethane	µg/L	NE	80	ND (152)	ND (303)	ND (1.2)	ND (48.5)	ND (1.2)	ND (24.2)	ND (12.1)	ND (6.1)	ND (1.2)
EPA 8260	Bromoform	µg/L	NE	80	ND (1650)	ND (3310)	ND (13.2)	ND (530)	ND (13.2)	ND (265)	ND (132)	ND (66.2)	ND (13.2)
EPA 8260	Bromomethane	µg/L	NE	NE	ND (625)	ND (1250)	ND (5)	ND (200)	ND (5)	ND (100)	ND (50)	ND (25)	ND (5)
EPA 8260	Carbon tetrachloride	µg/L	5	5	ND (449)	ND (897)	ND (3.6)	ND (144)	ND (3.6)	ND (71.8)	ND (35.9)	ND (17.9)	ND (3.6)
EPA 8260	Chlorobenzene	µg/L	NE	100	ND (296)	ND (592)	ND (2.4)	ND (94.8)	ND (2.4)	ND (47.4)	ND (23.7)	ND (11.8)	ND (2.4)
EPA 8260	Chloroethane	µg/L	400	NE	ND (625)	ND (1250)	ND (5)	ND (200)	ND (5)	ND (100)	ND (50)	ND (25)	ND (5)
EPA 8260	Chloroform	µg/L	6	80	ND (625)	ND (1250)	ND (5)	ND (200)	ND (5)	ND (100)	eh	ND (25)	ND (5)
EPA 8260	Chloromethane	µg/L	3	NE	ND (912)	ND (1820)	ND (7.3)	ND (292)	ND (7.3)	ND (146)	ND (73)	ND (36.5)	ND (7.3)
EPA 8260	cis-1,2-Dichloroethene	µg/L	70	70	ND (125)	ND (250)	ND (1)	ND (40)	ND (1)	ND (20)	ND (10)	ND (5)	ND (1)
EPA 8260	cis-1,3-Dichloropropene	µg/L	0.2	NE	ND (1510)	ND (3020)	ND (12.1)	ND (484)	ND (12.1)	ND (242)	ND (121)	ND (60.5)	ND (12.1)
EPA 8260	Dibromochloromethane	µg/L	NE	80	ND (1080)	ND (2170)	ND (8.7)	ND (347)	ND (8.7)	ND (173)	ND (86.7)	ND (43.4)	ND (8.7)
EPA 8260	Dibromomethane	µg/L	NE	NE	ND (390)	ND (781)	ND (3.1)	ND (125)	ND (3.1)	ND (62.5)	ND (31.2)	ND (15.6)	ND (3.1)
EPA 8260	Dichlorodifluoromethane	µg/L	1,000	NE	ND (625)	ND (1250)	ND (5)	ND (200)	ND (5)	ND (100)	ND (50)	ND (25)	ND (5)
EPA 8260	Diisopropyl ether	µg/L	NE	NE	ND (787)	ND (1570)	ND (6.3)	ND (252)	ND (6.3)	ND (126)	ND (62.9)	ND (31.5)	ND (6.3)
EPA 8260	Ethylbenzene	µg/L	700	700	4310	2870	0.57 J	1130	ND (1.1)	3870	385	382	10.8
EPA 8260	Hexachloro-1,3-butadiene	µg/L	NE	NE	ND (610)	ND (1220)	ND (4.9)	ND (195)	ND (4.9)	ND (97.6)	ND (48.8)	ND (24.4)	ND (4.9)
EPA 8260	Isopropylbenzene (Cumene)	µg/L	NE	NE	ND (702)	ND (1400)	ND (5.6)	ND (225)	ND (5.6)	78.1 J	ND (56.2)	9.4 J	2.5 J
EPA 8260	m&p-Xylene	µg/L	10,000	10,000	14300	9080	11.6	3130	0.57 J	13800	562	538	17.9
EPA 8260	Methylene Chloride	µg/L	5	5	ND (625)	ND (1250)	ND (5)	ND (200)	ND (5)	ND (100)	ND (50)	ND (25)	ND (5)
EPA 8260	Methyl-tert-butyl ether	µg/L	60	NE	ND (519)	ND (1040)	ND (4.2)	ND (166)	ND (4.2)	ND (83.1)	ND (41.5)	ND (20.8)	ND (4.2)
EPA 8260	Naphthalene	µg/L	40	NE	702	414 J	ND (5)	197 J	ND (5)	575	25.8 J	29.9	4.7 J
EPA 8260	n-Butylbenzene	µg/L	NE	NE	ND (295)	ND (590)	ND (2.4)	ND (94.4)	ND (2.4)	ND (47.2)	ND (23.6)	ND (11.8)	13.9
EPA 8260	n-Propylbenzene	µg/L	NE	NE	311 J	ND (1250)	ND (5)	87.2 J	ND (5)	245	26.4 J	25.1	11.2
EPA 8260	o-Xylene	µg/L	10,000	10,000	7130	5120	9	1060	ND (1)	3410	3.8 J	4 J	0.66 J
EPA 8260	p-Isopropyltoluene	µg/L	NE	NE	ND (333)	ND (667)	ND (2.7)	ND (107)	ND (2.7)	ND (53.3)	ND (26.7)	ND (13.3)	ND (2.7)

Table 1 November 2020 Groundwater Analytical Results (continued)

Sample ID					MW-20	MW-20D	MW-21D	MW-21M	MW-23D	MW-23S	MW-24D	MW-25D	MW-24S
Monitoring Well ID					MW-20	MW-20D	MW-21D	MW-21M	MW-23D	MW-23S	MW-24D		MW-24S
Collection Date/Time					11/17/2020 12:40	11/17/2020 11:40	11/17/2020 13:05	11/17/2020 14:45	11/17/2020 9:45	11/17/2020 11:45	11/16/2020 13:45	11/16/2020 14:00	11/16/2020 15:45
Lab Sample ID					10539600007	10539600008	10539600010	10539600012	10539600009	10539600011	10539600003	10539600001	10539600002
Matrix					Water	Water	Water	Water	Water	Water	Water	Water	Water
Quality Control Sample Type					Primary	Primary	Primary	Primary	Primary	Primary	Primary	Duplicate of MW-24D	Primary
Analytical Method	Analyte	Units	LDF Groundwater Cleanup Standards ¹	EPA MCLs ²	Analytical Results								
EPA 8260	sec-Butylbenzene	µg/L	NE	NE	ND (625)	ND (1250)	ND (5)	ND (200)	ND (5)	ND (100)	ND (50)	ND (25)	5.3
EPA 8260	Styrene	µg/L	100	100	ND (1250)	ND (2510)	ND (10)	ND (401)	ND (10)	ND (201)	ND (100)	ND (50.2)	ND (10)
EPA 8260	tert-Butylbenzene	µg/L	NE	NE	ND (127)	ND (253)	ND (1)	ND (40.5)	ND (1)	ND (20.3)	ND (10.1)	ND (5.1)	ND (1)
EPA 8260	Tetrachloroethene	µg/L	NE	5	ND (136)	ND (272)	ND (1.1)	ND (43.5)	ND (1.1)	ND (21.8)	ND (10.9)	ND (5.4)	ND (1.1)
EPA 8260	Toluene	µg/L	1,000	1,000	10500	29900	0.65 J	390	ND (1)	256	12.7	13.5	0.47 J
EPA 8260	trans-1,2-Dichloroethene	µg/L	100	NE	ND (193)	ND (387)	ND (1.5)	ND (61.9)	ND (1.5)	ND (30.9)	ND (15.5)	ND (7.7)	ND (1.5)
EPA 8260	trans-1,3-Dichloropropene	µg/L	0.2	NE	ND (1820)	ND (3640)	ND (14.6)	ND (583)	ND (14.6)	ND (291)	ND (146)	ND (72.8)	ND (14.6)
EPA 8260	Trichloroethene	µg/L	5	NE	ND (125)	ND (250)	ND (1)	ND (40)	ND (1)	ND (20)	ND (10)	ND (5)	ND (1)
EPA 8260	Trichlorofluoromethane	µg/L	3,490	NE	ND (125)	ND (250)	ND (1)	ND (40)	ND (1)	ND (20)	ND (10)	ND (5)	ND (1)
EPA 8260	Vinyl chloride	µg/L	0.2	NE	ND (125)	ND (250)	ND (1)	ND (40)	ND (1)	ND (20)	ND (10)	ND (5)	ND (1)
EPA 8260	Xylenes, Total	µg/L	10,000	10,000	21400	14200	20.6	4190	0.57 J	17210	566	542	18.56

Notes:

¹Groundwater Cleanup Standards from Appenedix A of the LDF Tribe's *Hazardous Substances Control Code*

²EPA MCLs established by the Safe Drinking Water Act

Bolded results exceed either an LDF Groundwater Cleanup Standard or an EPA MCL

Grey shaded ND results have LOQs that exceed the LDF Groundwater Cleanup Standard or EPA MCL

µg/L = micrograms per liter
EPA = U.S. Environmental Protection Agency
ID = identification
J = Positive result is less than the LOQ and considered an estimate
LDF = Lac du Flambeau
LOD = Limit of detection
LOQ = Limit of quantitation
MCL = Maximum Contaminant Level
NE = not established
ND = Result is non-detect with Limit of Quantitation (LOQ) in parentheses

Table 2 Pilot Study Vapor Analytical Results

			Vapor Samples Collected During Soil Vapor Extraction System Operation												
	Sample ID		ASVE-1	ASVE-1D	ASVE-2	ASVE-2D	ASVE-3	ASVE-4	ASVE-5	ASVE-6	AVP-1	AVP-2	AVP-3	AGAC IN	AGAC OUT
	Collection Date/Time		11/19/2020 12:45	11/19/2020 13:20	11/19/2020 12:50	11/19/2020 13:40	11/19/2020 13:07	11/19/2020 13:10	11/19/2020 13:13	11/19/2020 13:17	11/19/2020 13:39	11/19/2020 13:49	11/19/2020 14:03	11/19/2020 13:26	11/19/2020 13:30
	Lab Sample ID		10539927001	10539927012	10539927002	10539927013	10539927003	10539927004	10539927005	10539927006	10539927007	10539927008	10539927009	10539927010	10539927011
	Matrix		Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air
Quality Control Sample Type			Primary	QC Field Duplicate of ASVE-1	Primary	QC Field Duplicate of ASVE-2	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary
Analytical Method	Analyte	Units	Analytical Results												
TO-15	1,1,1-Trichloroethane	µg/m³	ND (1990)	ND (7800)	ND (7970)	ND (7670)	ND (1990)	ND (2110)	ND (2070)	ND (2070)	ND (2)	ND (2.1)	ND (2.2)	ND (2440)	ND (2.1)
TO-15	1,1,2,2-Tetrachloroethane	µg/m³	ND (1250)	ND (4900)	ND (5010)	ND (4820)	ND (1250)	694 J	ND (1300)	ND (1300)	ND (1.2)	ND (1.3)	ND (1.4)	ND (1530)	ND (1.3)
TO-15	1,1,2-Trichloroethane	µg/m³	ND (996)	ND (3900)	ND (3990)	ND (3840)	ND (996)	ND (1050)	ND (1030)	ND (1030)	ND (0.98)	ND (1.1)	ND (1.1)	ND (1220)	ND (1.1)
TO-15	1,1,2-Trichlorotrifluoroethane	µg/m³	ND (2800)	ND (11000)	ND (11200)	ND (10800)	ND (2800)	ND (2970)	ND (2910)	ND (2910)	0.59 J	0.54 J	0.5 J	ND (3430)	ND (3)
TO-15	1,1-Dichloroethane	µg/m³	ND (1480)	ND (5780)	ND (5910)	ND (5690)	ND (1480)	ND (1560)	ND (1530)	ND (1530)	ND (1.5)	ND (1.6)	ND (1.7)	ND (1810)	ND (1.6)
TO-15	1,1-Dichloroethene	µg/m³	ND (1450)	ND (5660)	ND (5790)	ND (5570)	ND (1450)	ND (1530)	ND (1500)	ND (1500)	ND (1.4)	ND (1.5)	ND (1.6)	ND (1770)	ND (1.5)
TO-15	1,2,4-Trichlorobenzene	µg/m³	ND (13500)	ND (53000)	ND (54100)	ND (52100)	ND (13500)	ND (14300)	ND (14000)	ND (14000)	ND (13.3)	ND (14.3)	ND (15.2)	ND (16600)	ND (14.3)
TO-15	1,2,4-Trimethylbenzene	µg/m³	1670 J	2430 J	ND (7170)	ND (6910)	12100	4710	8550	12200	6.6	3.8	79.2	81100	2.1
TO-15	1,2-Dibromoethane (EDB)	µg/m³	ND (1400)	ND (5490)	ND (5610)	ND (5400)	ND (1400)	ND (1480)	ND (1450)	ND (1450)	ND (1.4)	ND (1.5)	ND (1.6)	ND (1720)	ND (1.5)
TO-15	1,2-Dichlorobenzene	µg/m³	ND (2190)	ND (8570)	ND (8760)	ND (8430)	ND (2190)	ND (2320)	ND (2270)	ND (2270)	ND (2.2)	ND (2.3)	ND (2.5)	ND (2680)	ND (2.3)
TO-15	1,2-Dichloroethane	µg/m³	ND (738)	ND (2890)	ND (2950)	ND (2840)	ND (738)	ND (781)	ND (765)	ND (765)	ND (0.73)	ND (0.78)	ND (0.83)	ND (904)	ND (0.78)
TO-15	1,2-Dichloropropane	µg/m³	ND (1690)	ND (6600)	ND (6740)	ND (6490)	ND (1690)	ND (1780)	ND (1750)	ND (1750)	ND (1.7)	ND (1.8)	ND (1.9)	ND (2060)	ND (1.8)
TO-15	1,3,5-Trimethylbenzene	µg/m³	971 J QN	2320 J QN	ND (7170)	ND (6910)	8250	4100	6520	9430	2.8	1.2 J	50.2	31100	1.3 J
TO-15	1,3-Butadiene	µg/m³	ND (808)	ND (3160)	ND (3230)	ND (3110)	ND (808)	ND (855)	ND (838)	ND (838)	ND (0.8)	ND (0.86)	ND (0.91)	ND (989)	ND (0.86)
TO-15	1,3-Dichlorobenzene	µg/m³	ND (2190)	ND (8570)	ND (8760)	ND (8430)	ND (2190)	ND (2320)	ND (2270)	ND (2270)	ND (2.2)	ND (2.3)	ND (2.5)	ND (2680)	ND (2.3)
TO-15	1,4-Dichlorobenzene	µg/m³	ND (5490)	ND (21500)	ND (22000)	ND (21200)	ND (5490)	ND (5820)	ND (5700)	ND (5700)	ND (5.4)	ND (5.8)	ND (6.2)	ND (6730)	ND (5.8)
TO-15	1,4-Dioxane (p-Dioxane)	µg/m³	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TO-15	2,2,4-Trimethylpentane	µg/m³	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TO-15	2-Butanone (MEK)	µg/m³	ND (5390)	ND (21100)	ND (21500)	ND (20700)	8390	ND (5700)	4730 J	6370	9.9	8.8	6.2	ND (6600)	3 J
TO-15	2-Chlorotoluene	µg/m³	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TO-15	2-Hexanone	µg/m³	ND (7470)	ND (29200)	ND (29900)	ND (28800)	ND (7470)	ND (7910)	ND (7750)	ND (7750)	ND (7.4)	3.4 J	ND (8.4)	ND (9150)	ND (7.9)
TO-15	2-Propanol	µg/m³	ND (4490)	ND (17600)	ND (18000)	ND (17300)	ND (4490)	ND (4750)	ND (4660)	ND (4660)	7.5	3.6 J	6.7	ND (5500)	5.9
TO-15	4-Ethyltoluene	µg/m³	3070 J QN	10700 J QN	9500 J	8830 J	8620	5800	7500	8990	4.3 J	3.1 J	37	26400	3 J
TO-15	4-Methyl-2-pentanone (MIBK)	µg/m³	ND (7470)	ND (29200)	ND (29900)	ND (28800)	ND (7470)	ND (7910)	ND (7750)	ND (7750)	1.7 J	1.1 J	ND (8.4)	ND (9150)	ND (7.9)
TO-15	Acetone	µg/m³	ND (10800)	ND (42400)	ND (43400)	ND (41700)	ND (10800)	ND (11500)	ND (11200)	ND (11200)	76.4	66.7	54	ND (13300)	14.5
TO-15	Allyl chloride	µg/m³	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TO-15	Benzene	µg/m³	29800	18400	1660 J QN	4150 QN	5230	2400	1350	4110	6.2	3.9	21.6	9440	0.35 J
TO-15	Benzyl chloride	µg/m³	ND (4720)	ND (18500)	ND (18900)	ND (18200)	ND (4720)	ND (5000)	ND (4900)	ND (4900)	ND (4.7)	ND (5)	ND (5.3)	ND (5780)	ND (5)
TO-15	Bromodichloromethane	µg/m³	ND (2440)	ND (9560)	ND (9770)	ND (9400)	ND (2440)	ND (2590)	ND (2530)	ND (2530)	ND (2.4)	ND (2.6)	ND (2.7)	ND (2990)	ND (2.6)
TO-15	Bromoform	µg/m³	ND (9420)	ND (36900)	ND (37700)	ND (36300)	ND (9420)	ND (9980)	ND (9780)	ND (9780)	ND (9.3)	ND (10)	ND (10.6)	ND (11500)	ND (10)
TO-15	Bromomethane	µg/m³	ND (1420)	ND (5540)	ND (5670)	ND (5450)	ND (1420)	ND (1500)	ND (1470)	ND (1470)	ND (1.4)	ND (1.5)	ND (1.6)	ND (1730)	ND (1.5)
TO-15	Carbon disulfide	µg/m³	ND (1140)	ND (4450)	ND (4550)	ND (4380)	ND (1140)	ND (1200)	ND (1180)	ND (1180)	ND (1.1)	0.69 J	6.1	ND (1390)	7.1
TO-15	Carbon tetrachloride	µg/m³	ND (2300)	ND (8990)	ND (9190)	ND (8850)	ND (2300)	ND (2430)	ND (2380)	ND (2380)	ND (2.3)	ND (2.4)	ND (2.6)	ND (2810)	ND (2.4)

Table 2 Pilot Study Vapor Analytical Results (continued)

			Vapor Samples Collected During Soil Vapor Extraction System Operation												
	Sample ID		ASVE-1	ASVE-1D	ASVE-2	ASVE-2D	ASVE-3	ASVE-4	ASVE-5	ASVE-6	AVP-1	AVP-2	AVP-3	AGAC IN	AGAC OUT
	Collection Date/Time		11/19/2020 12:45	11/19/2020 13:20	11/19/2020 12:50	11/19/2020 13:40	11/19/2020 13:07	11/19/2020 13:10	11/19/2020 13:13	11/19/2020 13:17	11/19/2020 13:39	11/19/2020 13:49	11/19/2020 14:03	11/19/2020 13:26	11/19/2020 13:30
	Lab Sample ID		10539927001	10539927012	10539927002	10539927013	10539927003	10539927004	10539927005	10539927006	10539927007	10539927008	10539927009	10539927010	10539927011
	Matrix		Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air
Quality Control Sample Type			Primary	QC Field Duplicate of ASVE-1	Primary	QC Field Duplicate of ASVE-2	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary
Analytical Method	Analyte	Units	Analytical Results												
TO-15	Chlorobenzene	µg/m³	ND (1680)	ND (6580)	ND (6720)	ND (6470)	ND (1680)	ND (1780)	ND (1740)	ND (1740)	ND (1.7)	ND (1.8)	ND (1.9)	ND (2060)	ND (1.8)
TO-15	Chloroethane	µg/m³	ND (962)	ND (3770)	ND (3850)	ND (3700)	ND (962)	ND (1020)	ND (998)	ND (998)	ND (0.95)	ND (1)	ND (1.1)	ND (1180)	ND (1)
TO-15	Chloroform	µg/m³	ND (890)	ND (3490)	ND (3560)	ND (3430)	ND (890)	ND (943)	ND (924)	ND (924)	ND (0.88)	ND (0.94)	ND (1)	ND (1090)	ND (0.94)
TO-15	Chloromethane	µg/m³	ND (754)	ND (2950)	ND (3020)	ND (2900)	ND (754)	ND (798)	ND (782)	ND (782)	1.1	1.3	1.4	ND (923)	1
TO-15	cis-1,2-Dichloroethene	µg/m³	ND (1450)	ND (5660)	ND (5790)	ND (5570)	ND (1450)	ND (1530)	ND (1500)	ND (1500)	ND (1.4)	ND (1.5)	ND (1.6)	ND (1770)	ND (1.5)
TO-15	cis-1,3-Dichloropropene	µg/m³	ND (1660)	ND (6490)	ND (6630)	ND (6380)	ND (1660)	ND (1750)	ND (1720)	ND (1720)	ND (1.6)	ND (1.8)	ND (1.9)	ND (2030)	ND (1.8)
TO-15	Cyclohexane	µg/m³	1600000 QN	387000 QN	59200 QN	208000 QN	547000	22800	14600	71100	10.1	7.9	55.1	254000	2.1 J
TO-15	Dibromochloromethane	µg/m³	ND (3110)	ND (12200)	ND (12400)	ND (12000)	ND (3110)	ND (3290)	ND (3220)	ND (3220)	ND (3.1)	ND (3.3)	ND (3.5)	ND (3800)	ND (3.3)
TO-15	Dichlorodifluoromethane	µg/m³	ND (1810)	ND (7100)	ND (7250)	ND (6980)	ND (1810)	ND (1920)	ND (1880)	ND (1880)	2.6	2.7	2.9	ND (2220)	ND (1.9)
TO-15	Dichlorotetrafluoroethane	µg/m³	ND (2550)	ND (9980)	ND (10200)	ND (9820)	ND (2550)	ND (2700)	ND (2640)	ND (2640)	ND (2.5)	ND (2.7)	ND (2.9)	ND (3120)	ND (2.7)
TO-15	Ethanol	µg/m³	ND (3450)	ND (13500)	ND (13800)	ND (13300)	ND (3450)	ND (3650)	ND (3580)	ND (3580)	63.4	60.3	54.5	ND (4220)	22.2
TO-15	Ethyl acetate	µg/m³	ND (1320)	ND (5150)	ND (5260)	ND (5070)	ND (1320)	ND (1390)	ND (1370)	ND (1370)	1.4	ND (1.4)	ND (1.5)	ND (1610)	ND (1.4)
TO-15	Ethylbenzene	µg/m³	61400 QN	137000 QN	7810	6180	84100	106000	83300	62800	14.8	3.9	251	117000	2.5
TO-15	Hexachloro-1,3-butadiene	µg/m³	ND (9730)	ND (38100)	ND (38900)	ND (37500)	ND (9730)	ND (10300)	ND (10100)	ND (10100)	ND (9.6)	ND (10.3)	ND (10.9)	ND (11900)	ND (10.3)
TO-15	Isopropylbenzene (Cumene)	µg/m³	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TO-15	m&p-Xylene	µg/m³	137000 QN	350000 QN	36200	30200	232000	324000	287000	156000	51.9	18.4	614	394000	6.4
TO-15	Methyl methacrylate	µg/m³	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TO-15	Methylene Chloride	µg/m³	ND (6340)	ND (24800)	ND (25300)	ND (24400)	ND (6340)	ND (6710)	ND (6570)	ND (6570)	ND (6.2)	ND (6.7)	ND (7.1)	ND (7760)	ND (6.7)
TO-15	Methyl-tert-butyl ether	µg/m³	ND (6570)	ND (25700)	ND (26300)	ND (25300)	ND (6570)	ND (6960)	ND (6820)	ND (6820)	ND (6.5)	ND (7)	ND (7.4)	ND (8050)	ND (7)
TO-15	Naphthalene	µg/m³	ND (4780)	ND (18700)	ND (19100)	ND (18400)	ND (4780)	ND (5060)	ND (4950)	ND (4950)	ND (4.7)	ND (5.1)	4.7 J	5300 J	ND (5.1)
TO-15	n-Heptane	µg/m³	1850000 QN	620000 QN	62100 QN	208000 QN	539000	44300	20200	109000	16.1	9.7	179	544000	3.3
TO-15	n-Hexane	µg/m³	613000 QN	120000 QN	23800 QN	82100 QN	146000	6810	4880	23100	6.6	13.1	19.2	88900	1.8
TO-15	o-Xylene	µg/m³	23800 QN	68000 QN	7190	5160 J	44500	74300	74300	21600	15.1	7.2	211	101000	2
TO-15	Propylene	µg/m³	588 J	ND (2460)	ND (2510)	ND (2420)	605 J	ND (665)	ND (652)	ND (652)	4.9	8.3	ND (0.71)	ND (769)	ND (0.66)
TO-15	Styrene	µg/m³	ND (1550)	ND (6090)	ND (6220)	ND (5990)	ND (1550)	ND (1650)	ND (1610)	ND (1610)	1.3 J	1.1 J	ND (1.7)	ND (1900)	ND (1.6)
TO-15	Tetrachloroethene	µg/m³	ND (1240)	ND (4840)	ND (4950)	ND (4760)	ND (1240)	ND (1310)	ND (1280)	ND (1280)	86.1	33.9	40.1	ND (1510)	ND (1.3)
TO-15	Tetrahydrofuran	µg/m³	ND (1080)	ND (4220)	ND (4310)	ND (4150)	104000	3130	28500	44900	7.2	ND (1.1)	ND (1.2)	ND (1320)	3.2
TO-15	THC as Gas	µg/m³	21900000	13300000	1840000 QN	4550000 QN	13400000	2360000	1610000	3640000	1150	814	7900	8290000	1470
TO-15	Toluene	µg/m³	136000	153000	1840 J	1390 J	19100	53600	28500	14900	38.1	19.3	65.7	62400	1.5
TO-15	trans-1,2-Dichloroethene	µg/m³	ND (1450)	ND (5660)	ND (5790)	ND (5570)	ND (1450)	ND (1530)	ND (1500)	ND (1500)	ND (1.4)	ND (1.5)	ND (1.6)	ND (1770)	ND (1.5)
TO-15	trans-1,3-Dichloropropene	µg/m³	ND (1660)	ND (6490)	ND (6630)	ND (6380)	ND (1660)	ND (1750)	ND (1720)	ND (1720)	ND (1.6)	ND (1.8)	ND (1.9)	ND (2030)	ND (1.8)
TO-15	Trichloroethene	µg/m³	ND (980)	ND (3840)	ND (3920)	ND (3770)	ND (980)	ND (1040)	ND (1020)	ND (1020)	ND (0.97)	ND (1)	ND (1.1)	ND (1200)	ND (1)
TO-15	Trichlorofluoromethane	µg/m³	ND (2050)	ND (8010)	ND (8190)	ND (7880)	ND (2050)	ND (2170)	ND (2120)	ND (2120)	1.8 J	1.6 J	1.6 J	ND (2510)	ND (2.2)
TO-15	Vinyl acetate	µg/m³	ND (1290)	ND (5030)	ND (5140)	ND (4950)	ND (1290)	ND (1360)	ND (1330)	ND (1330)	ND (1.3)	ND (1.4)	ND (1.4)	ND (1570)	ND (1.4)
TO-15	Vinyl bromide	µg/m³	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
TO-15	Vinyl chloride	µg/m³	ND (467)	ND (1830)	ND (1870)	ND (1800)	ND (467)	ND (494)	ND (484)	ND (484)	ND (0.46)	ND (0.49)	ND (0.53)	ND (572)	ND (0.49)

Notes:
µg/m³ = Micrograms per Cubic Meter of Air
ID = identification
J = Positive result is less than the LOQ and considered an estimate
LOQ = Limit of quantitation
ND = Result is non-detect with Limit of Quantitation (LOQ) in parentheses
QN = result is considered an estimated value with an unknown bias
R = Result was rejected by data review

Table 2 Pilot Study Vapor Analytical Results (continued)

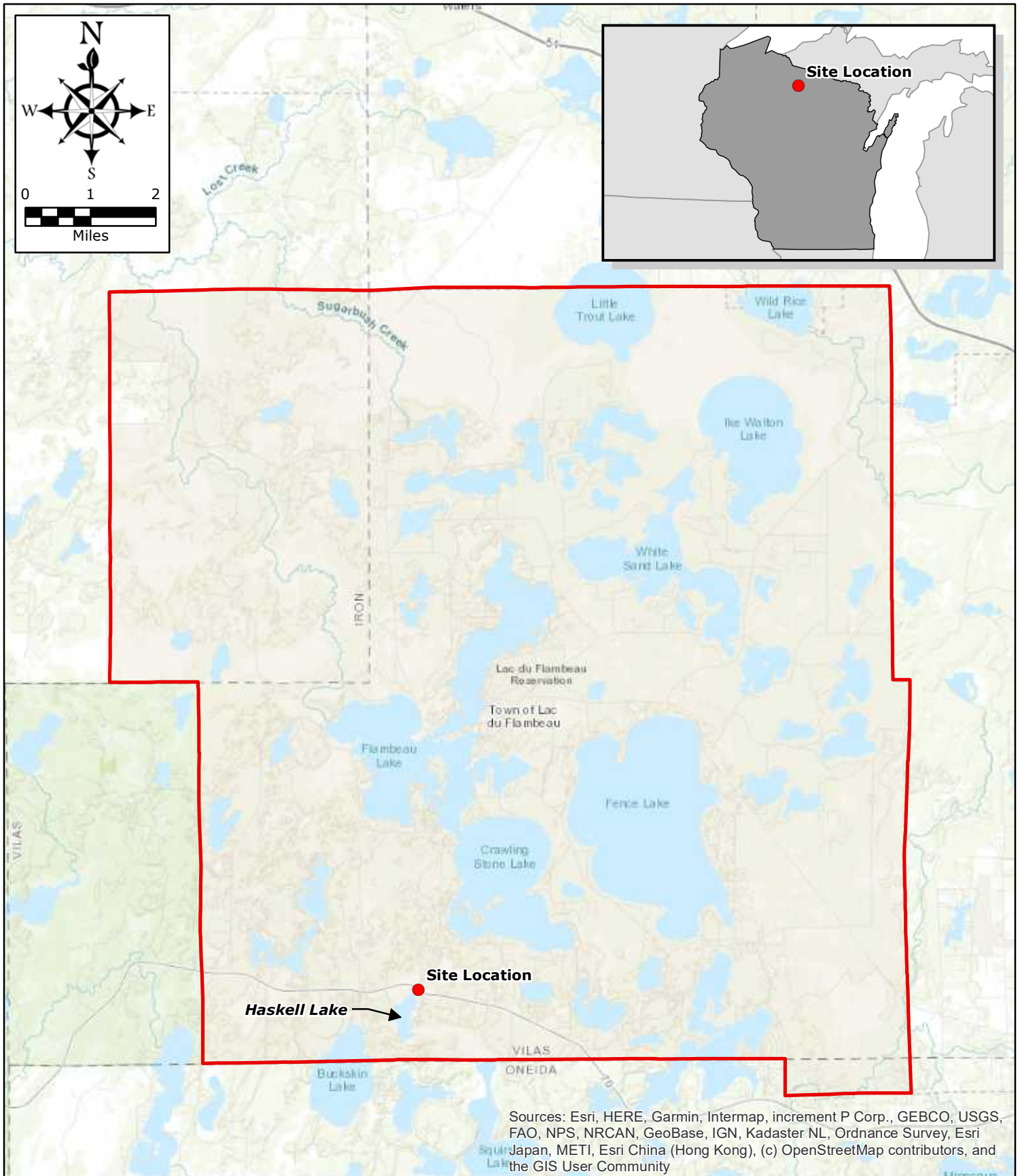
			Vapor Samples Collected During Combined Air Sparge/Soil Vapor Extraction System Operation												
			BSVE-1	BSVE-1D	BSVE-2	BSVE-2D	BSVE-3	BSVE-4	BSVE-5	BSVE-6	BVP-1	BVP-2	BVP-3	BGACIN	BGACOUT
			11/20/2020 14:00	11/20/2020 14:07	11/20/2020 14:01	11/20/2020 14:11	11/20/2020 14:14	11/20/2020 14:17	11/20/2020 14:22	11/20/2020 14:28	11/20/2020 14:31	11/20/2020 14:45	11/20/2020 14:57	11/20/2020 14:20	11/20/2020 14:30
			10540291001	10540291012	10540291002	10540291013	10540291003	10540291004	10540291005	10540291006	10540291007	10540291008	10540291009	10540291010	10540291011
			Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air
Quality Control Sample Type			Primary	QC Field Duplicate of BSVE-1	Primary	QC Field Duplicate of BSVE-2	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary
Analytical Method	Analyte	Units	Analytical Results												
TO-15	1,1,1-Trichloroethane	µg/m³	ND (5170) R	ND (2.49) R	ND (129)	ND (48.8)	ND (480)	ND (236)	ND (5060)	ND (125)	ND (129)	ND (116)	ND (132)	ND (280)	ND (2.44)
TO-15	1,1,2,2-Tetrachloroethane	µg/m³	ND (6610) R	ND (3.19) R	ND (166)	ND (62.4)	ND (614)	ND (302)	ND (6470)	ND (159)	ND (166)	ND (148)	ND (169)	ND (358)	ND (3.12)
TO-15	1,1,2-Trichloroethane	µg/m³	ND (5440) R	ND (2.62) R	315 QN	ND (51.4) QN	ND (505)	ND (249)	ND (5330)	ND (131)	ND (136)	ND (122)	ND (139)	ND (295)	ND (2.57)
TO-15	1,1,2-Trichlorotrifluoroethane	µg/m³	ND (7820) R	ND (3.79) R	ND (196)	ND (74)	ND (728)	ND (358)	ND (7660)	ND (189)	ND (196)	ND (176)	ND (200)	ND (425)	ND (3.7)
TO-15	1,1-Dichloroethane	µg/m³	ND (3750) R	ND (1.81) R	ND (93.8)	ND (35.4)	ND (348)	ND (171)	ND (3670)	ND (90.2)	ND (93.8)	ND (84.2)	ND (95.8)	ND (203)	ND (1.77)
TO-15	1,1-Dichloroethene	µg/m³	ND (3910) R	ND (1.88) R	ND (97.5)	ND (36.9)	ND (362)	ND (178)	ND (3820)	ND (93.9)	ND (97.5)	ND (87.6)	ND (99.5)	ND (211)	ND (1.84)
TO-15	1,2,4-Trichlorobenzene	µg/m³	ND (14100) R	ND (6.83) R	ND (354)	ND (133)	ND (1310)	ND (646)	ND (13800)	ND (341)	ND (354)	ND (318)	ND (361)	ND (770)	ND (6.68)
TO-15	1,2,4-Trimethylbenzene	µg/m³	ND (4850) R	103 QN	422	328	19500	555	18300	9870	149	44.6 J	137	48500	1.16 J
TO-15	1,2-Dibromoethane (EDB)	µg/m³	ND (7160) R	ND (3.45) R	ND (179)	ND (67.5)	ND (664)	ND (327)	ND (7010)	ND (172)	ND (179)	ND (161)	ND (183)	ND (388)	ND (3.38)
TO-15	1,2-Dichlorobenzene	µg/m³	ND (9980) R	ND (4.8) R	ND (249)	ND (93.8)	ND (926)	ND (455)	ND (9740)	ND (240)	ND (249)	ND (223)	ND (254)	ND (539)	ND (4.7)
TO-15	1,2-Dichloroethane	µg/m³	ND (3660) R	ND (1.77) R	160 QN	ND (34.5) QN	ND (340)	ND (167)	ND (3580)	ND (88.3)	ND (91.5)	ND (82.2)	ND (93.5)	ND (198)	ND (1.72)
TO-15	1,2-Dichloropropane	µg/m³	ND (4540) R	ND (2.19) R	164 QN	ND (42.8) QN	ND (421)	ND (207)	ND (4440)	ND (110)	ND (113)	ND (102)	ND (116)	ND (245)	ND (2.14)
TO-15	1,3,5-Trimethylbenzene	µg/m³	ND (4960) R	76.6 QN	374	272	9960	372	10900	5940	68.7 J	ND (111)	90.8 J	23700	ND (2.34)
TO-15	1,3-Butadiene	µg/m³	ND (2990) R	ND (1.44) R	ND (74.6)	ND (28.1)	ND (277)	ND (136)	ND (2920)	ND (71.7)	ND (74.6)	ND (66.8)	ND (76.1)	ND (161)	ND (1.41)
TO-15	1,3-Dichlorobenzene	µg/m³	ND (14200) R	ND (6.85) R	ND (354)	ND (133)	ND (1320)	ND (643)	ND (13900)	ND (341)	ND (354)	ND (317)	ND (361)	ND (764)	ND (6.67)
TO-15	1,4-Dichlorobenzene	µg/m³	ND (4340) R	ND (2.09) R	ND (108)	ND (40.9)	ND (403)	ND (198)	ND (4250)	ND (105)	ND (108)	ND (97.4)	ND (111)	ND (235)	ND (2.04)
TO-15	1,4-Dioxane (p-Dioxane)	µg/m³	ND (3890) R	ND (1.87) R	ND (97.3)	ND (36.8)	ND (360)	ND (177)	ND (3820)	ND (93.7)	ND (97.3)	ND (87.2)	ND (99.1)	ND (210)	ND (1.83)
TO-15	2,2,4-Trimethylpentane	µg/m³	1140000	1280000	46600 QN	156000 QN	514000	361000	2240000	168000	4340	256	321	673000	ND (3.79)
TO-15	2-Butanone (MEK)	µg/m³	ND (3100) R	105 QN	593	475	ND (288)	ND (142)	ND (3040)	ND (74.6)	ND (77.6)	82.6	ND (79)	ND (168)	3.27
TO-15	2-Chlorotoluene	µg/m³	ND (5510) R	8.61 QN	ND (138) QN	33.5 J QN	ND (512)	ND (252)	ND (5410)	675	ND (138)	ND (124)	ND (141)	2680	ND (2.6)
TO-15	2-Hexanone	µg/m³	ND (7030) R	ND (3.39) R	204 QN	ND (66.3) QN	ND (650)	ND (321)	ND (6870)	ND (169)	ND (176)	ND (157)	ND (180)	ND (380)	ND (3.32)
TO-15	2-Propanol	µg/m³	52400 QN	ND (4.06) R	6660 QN	ND (79.2) QN	6440	12400	47400	142000	16100	6070	12100	15800	ND (3.96)
TO-15	4-Ethyltoluene	µg/m³	2070 J QN	356 QN	1290 QN	991 QN	38000	1270	32000	18700	149	36.5 J	242	76100	1.79 J
TO-15	4-Methyl-2-pentanone (MIBK)	µg/m³	ND (4050) R	ND (1.95) R	741 QN	ND (38.2) QN	ND (376)	ND (185)	ND (3970)	ND (97.4)	ND (101)	ND (90.9)	ND (103)	ND (219)	10.4
TO-15	Acetone	µg/m³	ND (18000) R	39 QN	620 QN	278 QN	506 J	ND (820)	ND (17600)	675	456	696	485	ND (974)	63.9
TO-15	Allyl chloride	µg/m³	ND (4600) R	ND (2.23) R	ND (115)	ND (43.5)	ND (429)	ND (211)	ND (4510)	ND (111)	ND (115)	ND (104)	ND (118)	ND (250)	ND (2.18)
TO-15	Benzene	µg/m³	32900	40200	1240 QN	3420 QN	5400	ND (134)	243000	33500	623	64.8 J	60.1 J	81100	0.802 J
TO-15	Benzyl chloride	µg/m³	ND (4010) R	ND (1.93) R	ND (100)	ND (37.8)	ND (372)	ND (183)	ND (3930)	ND (96.6)	ND (100)	ND (89.9)	ND (102)	ND (217)	ND (1.89)
TO-15	Bromodichloromethane	µg/m³	ND (6090) R	ND (2.94) R	2150 QN	ND (57.4) QN	ND (565)	ND (278)	ND (5960)	ND (147)	ND (152)	ND (137)	ND (156)	ND (329)	ND (2.87)
TO-15	Bromoform	µg/m³	ND (9800) R	ND (4.72) R	ND (245)	ND (92.4)	ND (909)	ND (447)	ND (9590)	ND (236)	ND (245)	ND (219)	ND (250)	ND (530)	ND (4.63)
TO-15	Bromomethane	µg/m³	ND (4930) R	ND (2.37) R	ND (123)	ND (46.6)	ND (458)	ND (225)	ND (4810)	ND (119)	ND (123)	ND (110)	ND (126)	ND (267)	ND (2.32)
TO-15	Carbon disulfide	µg/m³	ND (4110) R	ND (1.98) R	ND (103)	ND (38.6)	ND (380)	ND (187)	ND (4020)	ND (99)	ND (103)	ND (92.1)	ND (105)	ND (222)	ND (1.94)
TO-15	Carbon tetrachloride	µg/m³	ND (5960) R	ND (2.87) R	ND (149)	ND (56.2)	ND (553)	ND (272)	ND (5840)	ND (144)	ND (149)	ND (134)	ND (152)	ND (322)	ND (2.82)

Table 2 Pilot Study Vapor Analytical Results (continued)

			Vapor Samples Collected During Combined Air Sparge/Soil Vapor Extraction System Operation													
			Sample ID	BSVE-1	BSVE-1D	BSVE-2	BSVE-2D	BSVE-3	BSVE-4	BSVE-5	BSVE-6	BVP-1	BVP-2	BVP-3	BGACIN	BGACOUT
			Collection Date/Time	11/20/2020 14:00	11/20/2020 14:07	11/20/2020 14:01	11/20/2020 14:11	11/20/2020 14:14	11/20/2020 14:17	11/20/2020 14:22	11/20/2020 14:28	11/20/2020 14:31	11/20/2020 14:45	11/20/2020 14:57	11/20/2020 14:20	11/20/2020 14:30
			Lab Sample ID	10540291001	10540291012	10540291002	10540291013	10540291003	10540291004	10540291005	10540291006	10540291007	10540291008	10540291009	10540291010	10540291011
			Matrix	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air	Air
Quality Control Sample Type			Primary	QC Field Duplicate of BSVE-1	Primary	QC Field Duplicate of BSVE-2	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	Primary	
Analytical Method	Analyte	Units	Analytical Results													
TO-15	Chlorobenzene	µg/m ³	ND (4950) R	ND (2.39) R	ND (124)	ND (46.7)	ND (461)	ND (226)	ND (4850)	ND (120)	ND (124)	ND (111)	ND (127)	ND (269)	ND (2.34)	
TO-15	Chloroethane	µg/m ³	ND (3400) R	ND (1.64) R	ND (84.9)	ND (32.2)	ND (317)	ND (155)	ND (3320)	ND (81.8)	ND (84.9)	ND (76.2)	ND (86.8)	ND (184)	ND (1.6)	
TO-15	Chloroform	µg/m ³	ND (4510) R	ND (2.18) R	161 QN	ND (42.6) QN	ND (419)	ND (206)	ND (4420)	ND (109)	ND (113)	ND (101)	ND (115)	ND (244)	ND (2.13)	
TO-15	Chloromethane	µg/m ³	ND (2750) R	ND (1.32) R	ND (68.8)	ND (26)	ND (254)	ND (125)	ND (2690)	ND (66.3)	ND (68.8)	ND (61.6)	ND (70.2)	ND (149)	ND (1.3)	
TO-15	cis-1,2-Dichloroethene	µg/m ³	ND (4000) R	ND (1.93) R	ND (100)	ND (37.8)	ND (373)	ND (183)	ND (3930)	ND (96.7)	ND (100)	ND (90)	ND (102)	ND (217)	ND (1.89)	
TO-15	cis-1,3-Dichloropropene	µg/m ³	ND (4050) R	ND (1.95) R	ND (101)	ND (38.2)	ND (376)	ND (185)	ND (3970)	ND (97.6)	ND (101)	ND (90.8)	ND (104)	ND (219)	ND (1.91)	
TO-15	Cyclohexane	µg/m ³	ND (3350) R	ND (1.62) R	12000 QN	34800 QN	ND (311)	211000	1220000	ND (80.9)	3080	520	527	ND (181)	ND (1.58)	
TO-15	Dibromochloromethane	µg/m ³	ND (7990) R	ND (3.85) R	ND (200)	ND (75.4)	ND (741)	ND (364)	ND (7830)	ND (192)	ND (200)	ND (180)	ND (204)	ND (432)	ND (3.77)	
TO-15	Dichlorodifluoromethane	µg/m ³	ND (8750) R	ND (4.23) R	ND (219)	ND (82.6)	ND (816)	ND (400)	ND (8610)	ND (211)	ND (219)	ND (197)	ND (224)	ND (475)	ND (4.13)	
TO-15	Dichlorotetrafluoroethane	µg/m ³	ND (8040) R	ND (3.88) R	ND (201)	ND (76.2)	ND (748)	ND (368)	ND (7900)	ND (194)	ND (201)	ND (180)	ND (206)	ND (436)	ND (3.8)	
TO-15	Ethanol	µg/m ³	ND (6470) R	ND (3.11) R	381 QN	ND (60.9) QN	513 J	ND (294)	ND (6340)	ND (156)	584	ND (145)	513	ND (349)	5.45	
TO-15	Ethyl acetate	µg/m ³	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	
TO-15	Ethylbenzene	µg/m ³	35500 QN	110000 QN	2930	3920	116000	2860	73300	42500	395	81.9 J	223	94900	1.47 J	
TO-15	Hexachloro-1,3-butadiene	µg/m ³	ND (14500) R	ND (6.99) R	ND (363)	ND (137)	ND (1350)	ND (661)	ND (14200)	ND (349)	ND (363)	ND (326)	ND (370)	ND (785)	ND (6.83)	
TO-15	Isopropylbenzene (Cumene)	µg/m ³	ND (4920) R	102 QN	279	281	4570	202 J	3810 J	2590	ND (123)	ND (111)	ND (126)	7180	ND (2.33)	
TO-15	m&p-Xylene	µg/m ³	78000 QN	264000 QN	15800	19000	271000	10900	176000	96700	1020	242	750	284000	4.32	
TO-15	Methyl methacrylate	µg/m ³	ND (4630) R	ND (2.24) R	12500 QN	ND (43.8) QN	ND (430)	ND (212)	ND (4550)	ND (112)	ND (116)	ND (104)	ND (118)	ND (251)	ND (2.19)	
TO-15	Methylene Chloride	µg/m ³	ND (4380) R	ND (2.12) R	68.4 J	ND (41.3)	ND (406)	ND (200)	ND (4310)	ND (106)	ND (110)	ND (98.6)	ND (112)	ND (238)	ND (2.07)	
TO-15	Methyl-tert-butyl ether	µg/m ³	ND (3020) R	ND (1.46) R	ND (75.7)	ND (28.5)	ND (280)	ND (138)	ND (2960)	ND (72.8)	ND (75.7)	ND (67.7)	ND (77.1)	ND (164)	ND (1.42)	
TO-15	Naphthalene	µg/m ³	ND (23800) R	ND (11.5) R	ND (592)	ND (224)	ND (2200)	ND (1080)	ND (23300)	ND (571)	ND (592)	ND (534)	ND (607)	ND (1290)	ND (11.2)	
TO-15	n-Heptane	µg/m ³	519000 QN	916000 QN	30500 QN	123000 QN	143000	143000	736000	135000	1920	243	244	429000	0.793 J	
TO-15	n-Hexane	µg/m ³	333000	272000	17500 QN	49700 QN	77600	1330000	6950000	255000	16600	8640	3180	1250000	1.9 J	
TO-15	o-Xylene	µg/m ³	13900 QN	48600 QN	2920 QN	3060 QN	89300	2090	29500	31000	195	66.3 J	233	75400	1.12 J	
TO-15	Propylene	µg/m ³	ND (2080) R	21 QN	114 QN	195 QN	ND (193)	ND (94.7)	ND (2030)	ND (50.1)	ND (52)	ND (46.7)	ND (53)	ND (112)	3.84	
TO-15	Styrene	µg/m ³	ND (4340) R	ND (2.09) R	96.1 J	ND (41)	ND (403)	ND (198)	ND (4250)	ND (105)	ND (108)	72.3 J	45.5 J	ND (235)	ND (2.05)	
TO-15	Tetrachloroethene	µg/m ³	ND (7130) R	ND (3.44) R	162 J	ND (67.4)	ND (663)	ND (326)	ND (6990)	ND (172)	342	1110	447	ND (386)	ND (3.37)	
TO-15	Tetrahydrofuran	µg/m ³	ND (2800) R	ND (1.35) R	21100 QN	ND (26.5) QN	ND (260)	ND (128)	ND (2750)	ND (67.5)	ND (70.2)	ND (62.8)	ND (71.7)	ND (152)	ND (1.32)	
TO-15	THC as Gas	µg/m ³	13200000	20600000	760000 QN	2440000 QN	6110000	6490000	35000000	4250000	107000	41300 J	30900 J	13900000	347 J	
TO-15	Toluene	µg/m ³	114000 QN	220000 QN	569 QN	1370 QN	75000	4110	166000	77600	689	293	169	145000	1.74 J	
TO-15	trans-1,2-Dichloroethene	µg/m ³	ND (3440) R	ND (1.66) R	ND (86)	ND (32.5)	ND (319)	ND (157)	ND (3370)	ND (82.8)	ND (86)	ND (77.3)	ND (88)	ND (186)	ND (1.62)	
TO-15	trans-1,3-Dichloropropene	µg/m ³	ND (4280) R	ND (2.06) R	ND (107)	ND (40.4)	ND (397)	ND (195)	ND (4190)	ND (103)	ND (107)	ND (95.8)	ND (109)	ND (232)	ND (2.02)	
TO-15	Trichloroethene	µg/m ³	ND (4720) R	ND (2.27) R	1010 QN	ND (44.5) QN	ND (438)	ND (215)	ND (4620)	ND (114)	ND (118)	ND (106)	ND (121)	ND (256)	ND (2.22)	
TO-15	Trichlorofluoromethane	µg/m ³	ND (5960) R	ND (2.87) R	ND (149)	ND (56.1)	ND (552)	ND (271)	ND (5840)	ND (143)	ND (149)	ND (134)	ND (152)	ND (322)	ND (2.81)	
TO-15	Vinyl acetate	µg/m ³	ND (5280) R	ND (2.55) R	52.5 J	ND (50)	ND (489)	ND (241)	ND (5180)	ND (127)	ND (132)	ND (119)	ND (135)	ND (286)	ND (2.49)	
TO-15	Vinyl bromide	µg/m ³	ND (4810) R	ND (2.32) R	ND (120)	ND (45.5)	ND (446)	ND (220)	ND (4720)	ND (116)	ND (120)	ND (108)	ND (123)	ND (261)	ND (2.27)	
TO-15	Vinyl chloride	µg/m ³	ND (3140) R	ND (1.51) R	ND (78.5)	ND (29.7)	ND (291)	ND (143)	ND (3070)	ND (75.4)	ND (78.5)	ND (70.3)	ND (80)	ND (170)	ND (1.48)	

Notes:
µg/m³ = Micrograms per Cubic Meter of Air
ID = identification
J = Positive result is less than the LOQ and considered an estimate
LOQ = Limit of quantitation
ND = Result is non-detect with Limit of Quantitation (LOQ) in place
QN = result is considered an estimated value with an unknown true value
R = Result was rejected by data review

FIGURES



Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Legend

- Site Location
- Lac du Flambeau Indian Reservation

FIGURE 1
LAC DU FLAMBEAU, WI
TOWER STANDARD LUST SITE
LOCATION MAP

Bristol

ENVIRONMENTAL
REMEDIAL SERVICES, LLC
Phone (907)563-0013 Fax (907)563-6713

DATUM:	Date: 1/28/2021	SHEET
NAD83	DWN. NAP	1
PROJECTION:	SCALE 1" = 2 mi	of
SP WI ZN FT	APPRVD. MF	1
Project No.		
34170026		

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Legend

- Vapor Monitoring Point
- Existing Monitoring Well
- Newly Installed Monitoring Well (Location Approximate)
- Drinking Water Well
- Shallow Air Sparge Well
- Deep Air Sparge Well
- Soil Vapor Extraction Well
- Approximate Extent of Total VOCs in Groundwater Over 10 ug/L Based on Historical Sampling
- Approximate Extent of Total VOCs in Soil Over 500 ug/kg Based on Historical Sampling
- Parcel

FIGURE 2
LAC DU FLAMBEAU, WI
TOWER STANDARD LUST SITE
SITE MAP

 Bristol ENVIRONMENTAL REMEDIAL SERVICES, LLC Phone (907)563-0013 Fax (907)563-6713	DATUM:	Date: 4/7/2021	SHEET 1 of 1
	PROJECTION:	DWN. NAP	
	SCALE:	1" = 50'	
	APPRVD. MF		
Project No. 34170026			

Document Path: G:\Jobs\34200032_Tower\Report-Working - Rev1\Maps\Figure3.mxd



Legend








-  Existing Monitoring Well
-  Newly Installed Monitoring Well (Location Approximate)
-  Shallow Air Sparge Well
-  Deep Air Sparge Well
-  Soil Vapor Extraction Well
-  Vapor Monitoring Point
-  Parcel

FIGURE 3
LAC DU FLAMBEAU, WI
TOWER STANDARD LUST SITE
PILOT TEST WORK AREA MAP

Bristol

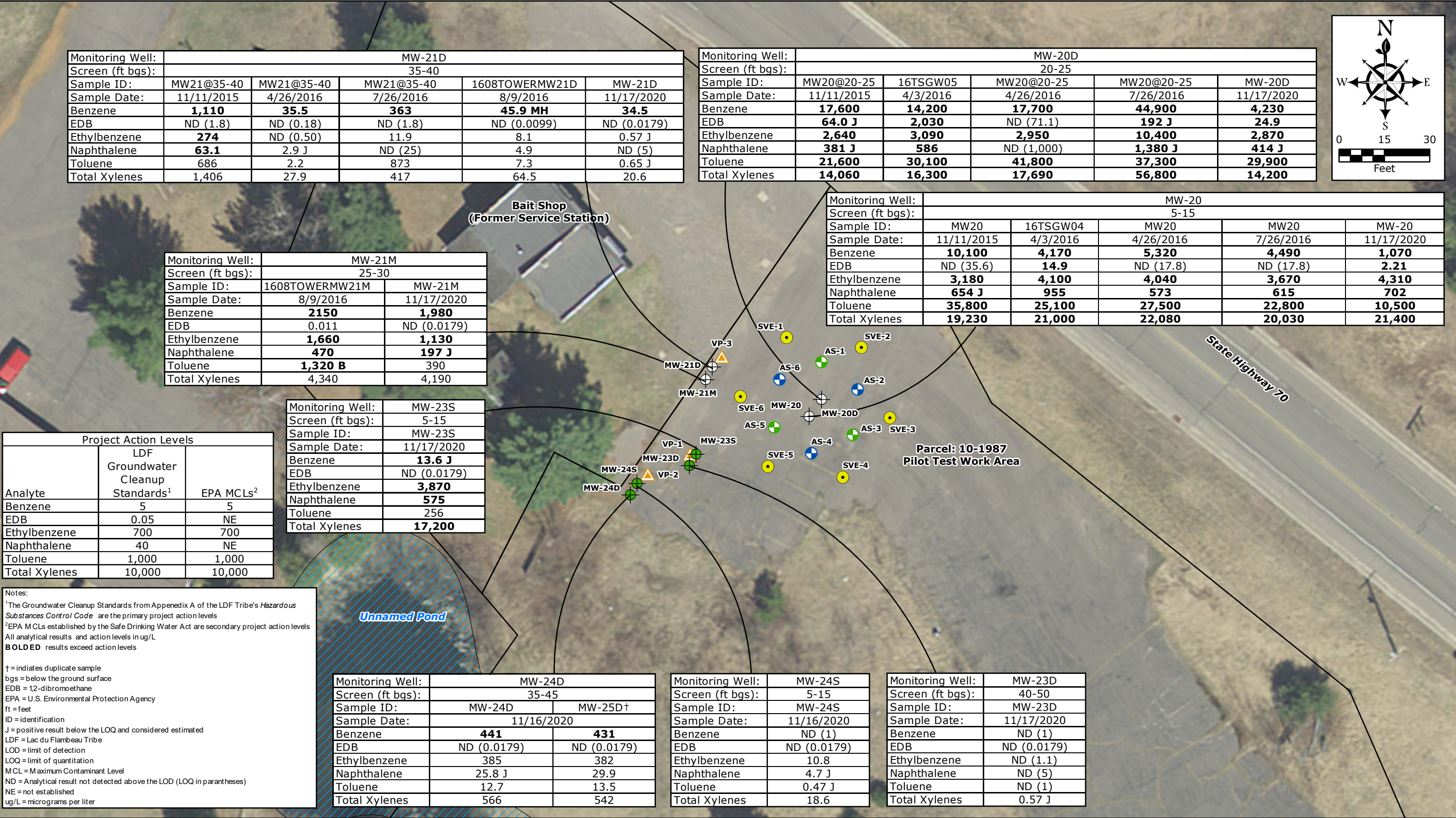
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DATUM:
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PROJECTION:
SP WI ZN FT
Project No.
34170026

Date: 4/7/2021
DWN. NAP
SCALE 1" = 30'
APPRVD. MF

SHEET
1
of
1

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Legend

- Existing Monitoring Well
- Newly Installed Monitoring Well (Location Approximate)
- Shallow Air Sparge Well
- Deep Air Sparge Well
- Soil Vapor Extraction Well
- Vapor Monitoring Point
- Parcel
- Hydrology

FIGURE 4
LAC DU FLAMBEAU, WI
TOWER STANDARD LUST SITE
NOVEMBER 2020 GROUNDWATER ANALYTICAL DATA

Bristol
ENVIRONMENTAL
REMEDATION SERVICES, LLC
Phone (907)563-0013 Fax (907)563-6713

DATUM: NAD83
PROJECTION: SP WI ZN FT
Project No. 34170026

Date: 4/7/2021
DWN. NAP
SCALE 1" = 30'
APPRVD. MF

SHEET 1
of 1

APPENDIX A

AS/SVE Pilot Test Report

SUBMITTED TO:
Bristol Environmental
Remediation Services, LLC
111 West 16th Avenue
Anchorage, AK 99501

BY:
Shannon & Wilson, Inc.
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REVISION III

PILOT TEST REPORT

Tower Standard Leaking Underground Storage Tank Site LAC DU FLAMBEAU, WI

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Submitted To: Bristol Environmental Remediation Services, LLC
111 West 16th Avenue
Anchorage, AK 99501
Attn: Mr. Matt Faust

Subject: REVISION III PILOT TEST REPORT, TOWER STANDARD LEAKING
UNDERGROUND STORAGE TANK SITE, LAC DU FLAMBEAU, WI

April 16, 2021

Shannon & Wilson is pleased to submit this revised pilot test report for the Tower Standard Service Gas Station and Auto Repair/Haskell Lake Contamination Site located in Lac du Flambeau, Wisconsin. The purpose of the pilot test was to evaluate the performance of soil vapor extraction enhanced with air sparging as a remedial technology to remove/reduce the concentrations of volatile organic compounds (VOCs) released to soil and groundwater. This pilot test report describes the results of an air sparge/soil vapor extraction (AS/SVE) system pilot test that was completed adjacent to the Tower Standard property. Please contact me at (608) 442-5223 if you should have any questions.

Sincerely,

SHANNON & WILSON, INC.

Mark A. Rutkowski, P. G.
Sr. Associate/Madison Office Manager

James L. Dutt, R.G.
Associate

JLD:MXR/tad

CONTENTS

1	Introduction	1
2	Pilot Test Physical Setting	2
2.1	Tower Standard Location	2
2.2	Groundwater Monitoring Well Network	2
2.3	Bristol Groundwater Sampling	2
3	AS/SVE Pilot System design	3
3.1	SVE System Array	3
3.2	AS System Array	3
3.2.1	AS/SVE System Components	4
3.3	Vapor Point Monitoring Locations	4
3.4	Conceptual Model	4
4	Pilot Test Activities	4
4.1	Field Work Narrative/Chronology	5
4.2	SVE System Performance	7
4.2.1	Step Test/Air Flow Calculations	7
4.2.2	Radius of Influence (ROI)	10
4.3	AS System Performance	12
4.3.1	Radius of Influence (ROI)	12
4.4	AS/SVE System Performance	13
4.4.1	Capture Effectiveness of SVE Wells to Sparged Air	13
4.4.2	Water Table Mounding	14
4.4.3	Potential for Iron Fouling	16
4.4.4	GAC System Performance	17
5	Mass Contaminant Recovery	18
5.1	SVE System Mass Contaminant Recovery	18
5.1.1	SVE Summa Canister Samples	19
5.2	AS/SVE System Mass Contaminant Recovery	20
5.2.1	AS/SVE Summa Canister Samples	20
5.3	AS/SVE System Zone Testing	21
6	AS/SVE Removal Rates	22

6.1	Summa Canister Mass Removal Rates	22
7	Conclusions.....	23
8	References	25

Tables

Table 1:	Tower Standard AS/SVE Pre-/Post GAC Effluent Gas (Attached)
Table 2.3:	Groundwater Monitoring Well Network
Table 4.2.1a:	Sample SCFM Calculation Parameters
Table 4.2.1b:	SVE Step Test/Air Flow Calculations
Table 4.2.2:	SVE Well Radius of Influence (ROI)
Table 4.4.1:	MW-20 DO Concentrations/Pre-GAC O ₂ % Measurements
Table 4.4.2:	AS/SVE Total System Test Water Level Data at Monitoring Wells
Table 4.4.3:	Monitoring Well Screened Interval and Dissolved Iron Concentrations
Table 5.1:	SVE System Step Test System Effluent Gas Monitoring
Table 5.1.1:	SVE System Effluent Gas Sample A
Table 5.2.1:	Total AS/SVE System Effluent Gas Sample B
Table 5.3:	AS/SVE Zone Testing
Table 6.2:	Mass Removal Based on Summa Canister Data

Figures

Figure 1:	Site Location Map
Figure 2:	AS/SVE/Monitoring Well and Vapor Point Location Map
Figure 3:	Cross Section of AS/SVE Wells
Figure 4:	SVE Radius of Influence Map
Figure 5:	AS Testing Water Levels
Figure 6:	AS/SVE Total System Testing Water Levels

Appendices

Appendix A:	AS/SVE Contractor Equipment
Appendix B:	Photographic Log
Appendix C:	SVE Well Data and Pressure v Distance Charts

ACRONYMS

AS	Air Sparge
bgs	Below Ground Surface
DO	Dissolved Oxygen
EPA	Environmental Protection Agency
GAC	Granulated Activated Carbon
GRO	Gasoline Related Organics
HASP	Health and Safety Plan
IDW	Investigation Derived Waste
KO	Knock Out
LEL	Lower Explosive Limit
LNAPL	Light Nonaqueous Phase Liquid
LUST	Leaking Underground Storage Tank
MS/MSD	Matrix Spike/Matrix Spike Duplicate
PID	Photoionization Detector
PVC	Polyvinyl Chloride
PVOC	Petroleum Volatile Organic Compound
QAPP	Quality Assurance Project Plan
RCLs	Residual Contaminant Levels
ROI	Radius of Influence
scfm	Standard Cubic Feet per Minute
SVE	Soil Vapor Extraction
USCS	Unified Soil Classification System
VOC	Volatile Organic Compound
W.C.	Water Column
WDNR	Wisconsin Department of Natural Resources

1 INTRODUCTION

Shannon & Wilson, Inc. (SWI) was contracted by Bristol Environmental Remediation Services, LLC (Bristol) as part of Bristol's contract (EP-W-12-009 Task Order (TO) 38HERH20F0243) with the U.S. Environmental Protection Agency (EPA) Region V for site investigation, characterization, and remediation of soil and groundwater impacts at the Sundberg property adjacent to the Tower Standard Service Gas Station and Auto Repair/Haskell Lake Contamination Site on the Lac du Flambeau Indian Reservation in Lac du Flambeau, Wisconsin (as referenced to by the Lac du Flambeau Band of the Lake Superior Chippewa Indians). This report was completed in partial fulfillment of an August 2020 document entitled: Pilot Test Plan – Tower Standard Leaking Underground Storage Tank Pilot Test (Pilot Test work plan or work plan).

As described in the work plan, SWI designed, installed, and operated an air sparge/soil vapor extraction (AS/SVE) system in order to evaluate the feasibility of air enhanced soil vapor extraction as a remedial strategy for the reduction of the total mass of residual soil and groundwater volatile organic compounds (VOCs) at the Sundberg property adjacent to the former Tower Standard LUST site.

The primary objective of the AS/SVE pilot test was to evaluate the performance of soil vapor extraction enhanced with air sparging in removing/reducing the concentrations of residual VOCs. Secondary performance objectives included:

- Calculation of the radius of influence (ROI) of SVE wells at various flow rates;
- Assessing the ROI of AS wells, at various flow rates and pressures;
- Assessing vertical mobility of sparged air to rise through subsurface and the smear zone;
- Determining capture effectiveness of SVE wells to sparged air;
- Observing water table mounding as a result of vapor extraction and air sparging;
- Assessing horizontal migration of the plume due to system operation;
- Calculating contaminant mass recovery rates (instantaneous and sustained);
- Monitoring SVE emissions; and
- Assessing the potential for Iron fouling.

The following sections describe the physical site characteristics as well as some of the parameters used from previous site investigation/site characterization reports as part of the AS/SVE system calculations.

2 PILOT TEST PHYSICAL SETTING

2.1 Tower Standard Location

The Tower Standard site is located near the intersection of Wisconsin State Highway 70W and County Road D in Lac du Flambeau, Wisconsin. While the release of contaminants was historically part of the Tower Standard property, the actual air sparge and soil vapor extraction wells and pilot test was completed on a contiguous parcel (Sundberg property) east of the Tower property. This Sundberg property (property) is listed as parcel number 10-1987 on the Vilas County on-line Land Records Map. Figure 1 (Site Location Map) depicts the location of the Tower Standard Site/Sundberg property on a portion of a United States Geological Service (USGS) internet topographic map.

2.2 Groundwater Monitoring Well Network

Prior to the start of the AS/SVE pilot test, Bristol installed 4 new groundwater monitoring wells to the existing monitoring well network in order to collect additional groundwater samples at the property. Table 2.2 summarizes the existing and new groundwater monitoring wells that were part of the AS/SVE pilot test.

Table 2.2. Groundwater Monitoring Well Network

Well ID	Existing/New	Total Depth (ft)	Well Screen Interval (ft-bgs)	Static Water Level (ft-bgs)
MW-20S	Existing	15	5-15	7.49
MW-20D	Existing	25	20-25	7.70
MW-21M	Existing	30	25-30	7.52
MW-21D	Existing	40	35-40	7.64
MW-23S	New	15	5-15	7.53
MW-23D	New	50	40-50	7.51
MW-24S	New	15	5-15	7.33
MW-24D	New	45	35-45	7.44

Static water level measurements recorded 11/18/2020

Ft BGS = feet below ground surface

2.3 Bristol Groundwater Sampling

Bristol collected a round of groundwater samples from four existing and four new groundwater monitoring wells prior to the operation of the AS/SVE pilot test. The results of the Bristol groundwater sample event are provided in a separate report document entitled Pilot Study Report (Bristol 2021).

3 AS/SVE PILOT SYSTEM DESIGN

The primary objective of the AS/SVE pilot test was to evaluate the performance of soil vapor extraction enhanced with air sparging in removing/reducing the concentrations of residual VOCs. In order to make this determination, the AS/SVE system array was centered around existing monitoring well nest MW-20/MW-20D. Groundwater samples collected by Bristol prior to the start-up of the AS/SVE pilot system confirmed that concentrations of petroleum-based VOCs were highest in monitoring wells MW-20/MW-20D. Details of the groundwater sample results are presented in the Bristol groundwater investigation report.

3.1 SVE System Array

Soil vapor extraction wells were organized in a hexagonal pattern centered on MW-20/MW-20D. Six SVE extraction points identified as SVE-1 through SVE-6 were placed approximately 25-ft from MW-20 and at 25-ft centers equidistant from each other. This 25-ft ROI spacing was anticipated to overlap each SVE location to ensure vapor capture even in potential AS/SVE “dead” zones within the array. Figure 2 (AS/SVE/Monitoring Well & Vapor Point Location Map) presents a map view of the locations of the SVE system array on the Sundberg property relative to the extent of impacted soil from 2017 Bristol site investigation reports.

SVE wells were drilled to a total depth of 13-feet below ground surface (ft bgs) using sonic drilling methods. The wells were constructed of 2-inch (in) diameter schedule 40-PVC with 10-ft long 010-in slot screens. SVE wells were constructed in accordance with the EPA approved pilot test work plan.

The SVE well screened interval was selected based on the historical depth to groundwater as well as the depth to groundwater observed by the Bristol field geologist during the recent field event. SVE wells were screened across the water table to account for seasonal changes in the water table while maintaining an unsaturated capture zone for off-gassing of impacted soil and groundwater vapors.

3.2 AS System Array

Six air sparge wells were similarly placed in a hexagonal array within the boundaries of the SVE array 15-ft from monitoring well MW-20 using a sonic drilling method. Sparge wells (shallow AS wells) AS-1, AS-3, and AS-5 were completed to a depth of 22-ft bgs while sparge wells AS-2, AS-4, and AS-6 (deep AS wells) were completed to 57-ft bgs. Alternate placement of shallow and deep AS wells around the array was completed in order to evaluate the performance of sparged air throughout the groundwater contaminant plume.

All AS well screened intervals were completed below the water table. Well screens were 2-ft long and constructed of 2-inch diameter stainless steel with 2-inch stainless-steel riser pipes. AS and SVE well construction reports are contained in the November 2020 Bristol groundwater sampling report. The AS configuration is presented in Figure 2.

3.2.1 AS/SVE System Components

AS/SVE system compressor, pump, and operating specifications as well as the operational system schematic are contained in Appendix A of this document.

3.3 Vapor Point Monitoring Locations

Three vapor monitoring points (VP-1, VP-2, and VP-3) were installed in the vicinity of groundwater monitoring well nests MW-24S/MW24-D (VP-1), MW-23S/MW-23D (VP-2) and MW-21M/MW-21D (VP-3). Boreholes for the vapor points were completed to a depth of 5-ft bgs. Each vapor point was constructed with a 0.5-ft long stainless-steel screen set from 3 ½ to 4-ft bgs. The stainless-steel screens were attached to poly-tubing that terminated just below the land surface inside a standard groundwater monitoring well flush-mount protective casing. Pressure measurements from the vapor monitoring points helped to determine the radius of influence of the AS/SVE system as well to determine if there was a buildup of contaminant vapors outside the SVE system. Locations of the vapor points are depicted in Figure 2.

3.4 Conceptual Model

Existing monitoring well construction logs, new monitoring well construction logs, as well as construction details for the air sparge wells, vapor extraction wells, and vapor monitoring points were used to create a geologic cross section (Figure 3) depicting the relationship between the screened intervals of the AS/SVE system wells and the new and existing groundwater monitoring well screened intervals. This cross section (A to A') is presented in Figure 2. With the addition of the shallow water table in profile view, the geologic cross section becomes a conceptual model that can be used to help understand the interaction between the AS/SVE system components and the shallow water table at the property.

4 PILOT TEST ACTIVITIES

A series of measurements and samples were collected prior to the startup of the AS/SVE system as well as during the different phases of the AS/SVE system operation. These tasks include:

- Collection of static water levels and groundwater field parameters;

- Obtaining background pressure measurements;
- Step testing of the SVE and AS system;
- Gas sample collection and continuous system effluent;
- Pressure and flow monitoring.

The following sections provide a chronology of the pilot test.

4.1 Field Work Narrative/Chronology

November 17, 2020: SWI staff assisted Bristol with the completion of groundwater sampling at monitoring wells MW-23S and MW-21D. Once groundwater sampling was completed, SWI and Specialty Systems, Inc. (SSI), the AS/SVE equipment contractor, set up manifolds, well couplings, pressure gauges, and other pieces of ancillary equipment for the pilot test run.

SVE effluent gas exhaust was soft-piped to two 55-gallon drums connected in series and filled with granulated activated carbon (GAC). The GAC was used as a filter for petroleum vapors removed from the subsurface prior to discharge to the atmosphere.

November 18, 2020: All onsite personnel participated in tailgate health & safety meeting. Discussed physical as well as chemical hazards associated with operation of AS/SVE system compressors and pumps. With six AS and six SVE wells and associated soft piping and hoses, discussed awareness of slips, trips, and falls in the context of the site activities. The morning tailgate meeting was completed each day prior to the commencement of work on site.

Static water level measurements were collected from the existing and newly constructed monitoring wells and from the shallow and deep AS wells and SVE extraction wells. ONSET HOBO pressure transducers were placed in wells SVE-1, SVE-2, SVE-3, SVE-5, SVE-6, MW-21M and MW-23S for continual measurement of static water levels. A background barometric pressure transducer was set up on site to document variations in atmospheric pressure that will be used to correct the static water level measurements.

Background static pressures were also collected from each well. Initial pressure at all of the wells was measured at 0.0 inches of water (in-H₂O). The SVE pilot test progressed by applying vacuum to each well in the following order: SVE-1, SVE-5, SVE-3, and SVE-2. Step tests were completed for each SVE well. During the SVE test at each SVE well, flow rates in standard cubic feet per minute (scfm) were calculated by SSI personal while operating their equipment. For each SVE well location where a vacuum was applied, pressure

measurements at perimeter SVE wells, vapor points, and groundwater monitoring wells were measured at discrete time intervals.

November 19, 2020: SVE system testing resumed at extraction wells SVE-4, SVE-6, and then for the entire SVE system. Once the pre-GAC PID measurements stabilized while the entire SVE system was running (approximately 50-minutes), the system isolated (shut off flow from) two well SVE pairs while the remaining four SVE wells remained active. Vapor samples were collected by Bristol personnel using 1,000-cubic centimeter Summa canisters from each of the SVE well pairs. SVE pairs isolated and sampled individually were SVE-1/SVE-2, SVE-3/SVE-4, and SVE-5/SVE-6. Pre- and post-GAC vapor samples were also collected while the system was running.

After collection of Summa canister vapor samples, the air sparge system testing began. Pressure measurements were collected at each of the SVE wells prior to starting the air sparge pumps. Dissolved oxygen (DO), conductivity, and static water levels were also measured at monitoring wells MW-20, MW-20D, MW-21D, and VP-3.

The initial AS system test was done primarily to make sure all fittings, pressure gauges and equipment were functional and there were no leaks in the above ground piping or compressor manifold. The testing began by pressurizing the shallow AS wells (AS-1, AS-3, and AS-5). On system start up, suspected leaks in gate valves were noted and repaired and test was restarted. Shallow AS system testing ran for one hour and 43 minutes. SSI installed whip cords on AS wells to prevent hose couplings (fastened by Fernco flexible couplers) from violently coming off AS well riser.

November 20, 2020: Conducted AS step test on deep sparge wells AS-2 and AS-4. Monitored DO, conductivity, and static water levels at the monitoring wells and vapor points. Shallow AS system test ran for approximately 55-minutes. The total AS/SVE system ran for approximately 40 minutes when adjustments to the air sparge flow valve were needed due to sparge air over-pressuring. The AS/SVE system was shut down to make the adjustments and then restarted and run from 11:30 to 14:00.

After deep well sparge step test, SSI ran the entire system (six SVE and six AS wells). SWI staff monitored pre- and post-GAC vapors as well as pressure, DO, conductivity, and static water levels at monitoring wells and vapor points (if accessible). Total AS/SVE system ran for approximately 2-hours. After two hours, Bristol personnel collected Summa canister gas samples from each of the SVE well locations.

Anomalous pressure measurements were observed between SVE-1 and SVE-2 in the field. At the initial start-up of Step 1 at SVE-1, a measurable pressure (-0.50 in-H₂O) was observed at SVE-2 (located 25-feet away from SVE-1). Subsequent pressure measurements at SVE-2

were recorded as 0.0 in-H₂O during the remaining steps and time increments during the testing at SVE-1. Measurable pressure responses were recorded for the other SVE wells during the test at SVE-1 including SVE-4 located 50-ft away from SVE-1. When the step test was initiated at SVE-2, a pressure response of -0.38 in-H₂O was observed at SVE-1. This response was not anticipated based on the pressure measurements at SVE-2 during the SVE-1 step test.

This non-reciprocal pressure response observed between SVE-1 and SVE-2 in an area where the subsurface soil is highly porous and permeable may be indicative of a number of issues with the extraction point SVE-2 itself including:

- Drilling method (sonic);
- Well construction issues (e.g. filter pack bridging, bentonite intrusion in well screen);
- Well design (continual screened versus slotted screen); and
- Well efficiency.

As a SVE well, SVE-2 was not developed so it is possible that some plugging of the screen may have occurred. Remedial actions to this SVE well such as surging (water slug, surge block, or compressed air) are recommended.

Regardless of the anomalous pressure response between SVE-1 and SVE-2, significant concentrations of gasoline volatile organic compounds were extracted at SVE-2. These results are discussed in the system performance section of this pilot test report.

At the completion of the test, pumps, blowers, soft-piping, manifolds, and all ancillary equipment were broken down and the site secured prior to SWI and field staff departure. Appendix B contains a photographic log of the field activities including AS/SVE system configuration, field equipment set-up, pre-post GAG monitoring, pressure, and groundwater field measurements.

4.2 SVE System Performance

4.2.1 Step Test/Air Flow Calculations

SVE pilot testing consisted of two step tests performed incrementally to determine the change on the radius of influence at different applied pressures and flow rates. Pressure calculations were used to determine the air flow in standard cubic feet per minute (scfm). The air flow was calculated by SSI using an in-house Excel™ work sheet created for the pilot test system parameters.

Equations used for the calculation of AS/SVE system flow in standard cubic feet per minute (scfm) are provided below. Equation 1 standardizes the AS/SVE system pressure to absolute atmospheric.

$$\text{EQ (1)} \quad \mathbf{PSIabs} = 14.7 - \left\lceil \frac{(BPc + Psve)}{27.68} \right\rceil$$

Where: PSIabs = Pounds per square inch absolute system
 BPc = Back pressure at carbon vessel (inches-H₂O)
 Psve = Pressure at SVE extraction well (inches-H₂O)
 27.68 = Conversion from inches-H₂O to pounds per square inch absolute
 14.7 = pounds per square inch atmospheric at surface

Equation 2 standardizes the AS/SVE system pressure relative to absolute temperature and adds a manufacturer's equipment design constant that incorporates the volume the piping over a predetermined time interval.

$$\text{EQ (2)} \quad \mathbf{scfm} = 200.65 * \sqrt{(PSIabs * DP) / (T + 460)}$$

Where: scfm = Standard cubic feet per minute
 PSIabs = Pounds per square inch absolute system
 DP = Differential pressure
 T = System temperature (measured in degrees Fahrenheit)
 460 = Conversion from Fahrenheit to Kelvin
 200.65 = Manufacturer's constant based on equipment pitot tube measurement and system piping diameter.

The input parameters utilized in equations 1 and 2 for scfm calculations at SVE-1 are provided in the Table 4.2.1a below.

Table 4.2.1a Sample SCFM Calculation Parameters

SVE-1 SCFM Calculation Parameters		
EQ (1) parameters	Value	Units
BP _c	16.27	inches-H ₂ O
P _{sve}	10	inches-H ₂ O
PSI _{abs}	13.73	psi absolute
EQ (2) parameters	Value	Units
DP	0.01	inches-H ₂ O
T	55	degrees F
scfm	3.27	flow in scfm

Step test pressures and the resulting air flow (calculated in scfm) are presented in table 4.2.1b below. Each step test was run for a minimum of two successive pressure measurements taken initially at a minimum 10-minute intervals (later extending to a minimum 15-minute interval). Additional step tests at different pressures were not possible as negligible or no measured responses were observed at lower flow rates for the system.

Table 4.2.1b SVE Step Test/Air Flow Calculations

Date	SVE Well	Test	pressure in-H ₂ O	Calculated Flow Rate (scfm)
11/18/2020	SVE-1	Step 1	-10.00	3.3
		Step 2	-34.00	14.4
		Step 2	-34.00	26.9
	SVE-2	Step 1	-10.00	4.6
		Step 2	-34.00	15.1
		Step 2	-34.00	15.8
	SVE-3	Step 1	-10.00	No measured response
		Step 2	-36.00	12.0
		Step 2	-36.00	13.2
		Step 2	-36.00	12.8
	SVE-5	Step 1	-10.00	10.4
		Step 1	-10.00	11.3
		Step 2	-19.00	27.4
		Step 2	-16.00	25.9
		Step 2	-16.00	29.0
11/19/2020	SVE-4	Step 1	-10.00	19.0
		Step 1	-10.00	18.5
		Step 1	-10.00	19.0
		Step 2	-13.00	26.4
		Step 2	-13.00	26.4
		Step 2	-13.00	26.4
	SVE-6	Step 1	-10.00	20.1
		Step 1	-10.00	20.1
		Step 2	-14.00	25.1
		Step 2	-14.00	25.1
		Step 2	-14.00	25.1

The change from step 1 to step 2 as well as the completion of an individual SVE well test were based on the SVE system pre-GAC PID and 4-gas meter measurements. Three or more pre-CAG PID/4-gas meters measurements without a significant change in concentration were used to indicate that the system was operating at a stable rate of extraction.

Use of two steps to evaluate the SVE system performance was a deviation from the pilot study work plan. Makeup air used to adjust the pressure (and air flow) was controlled by a simple ball valve opened to 70% in order to achieve the pressures and calculated flow volumes for Step 1 of the step test. Step 2 pressure and flows were achieved when the make-up air ball valve was completely closed. There was no intermediate pressure attainable using the pilot test available equipment.

4.2.2 Radius of Influence (ROI)

ROI determinations were evaluated for every SVE extraction point along the hexagonal array. A known pressure (measured in in-H₂O) was applied to each SVE well with pressure measurements collected from the other SVE, groundwater monitoring and vapor point observation wells at specific measured time intervals. Pressure measurements were collected with a magnehelic pressure meter and recorded on prepared field worksheets.

Log Pressure vs Distance plots were created for each SVE well to illustrate the radius of influence observed at each SVE location. Data used for these plots were the last pressure measurement taken after the pressure and pre-GAC had stabilized in Step 2.

The plot below provides an example of the Log Pressure vs Distance for SVE-1. According to the SVE standard practice, a response of 0.1 in-H₂O or greater indicates that the vapor monitoring points are within the SVE ROI for vapor recovery purposes. In the example provided for the SVE-1, Pressure vs Distance plot, pressure at observations points VP-3, MW-20, SVE-3, SVE-5, MW-23S and SVE-4 all were above the 0.1 in-H₂O threshold indicating that vapor recovery will occur at SVE-1 from these observation points.

As noted above, the pressure (in-H₂O) is plotted on the Y (logarithmic) scale while distance on the X-axis is plotted as a linear function. The dotted light blue diagonal line across the graph represents a best-fit trend analysis using an exponential equation. For display purposes, zero values are displayed on the graph as 0.0001. The remaining SVE Log vs Distance data plots (including SVE-1 from below) can be found in Appendix B of this report.

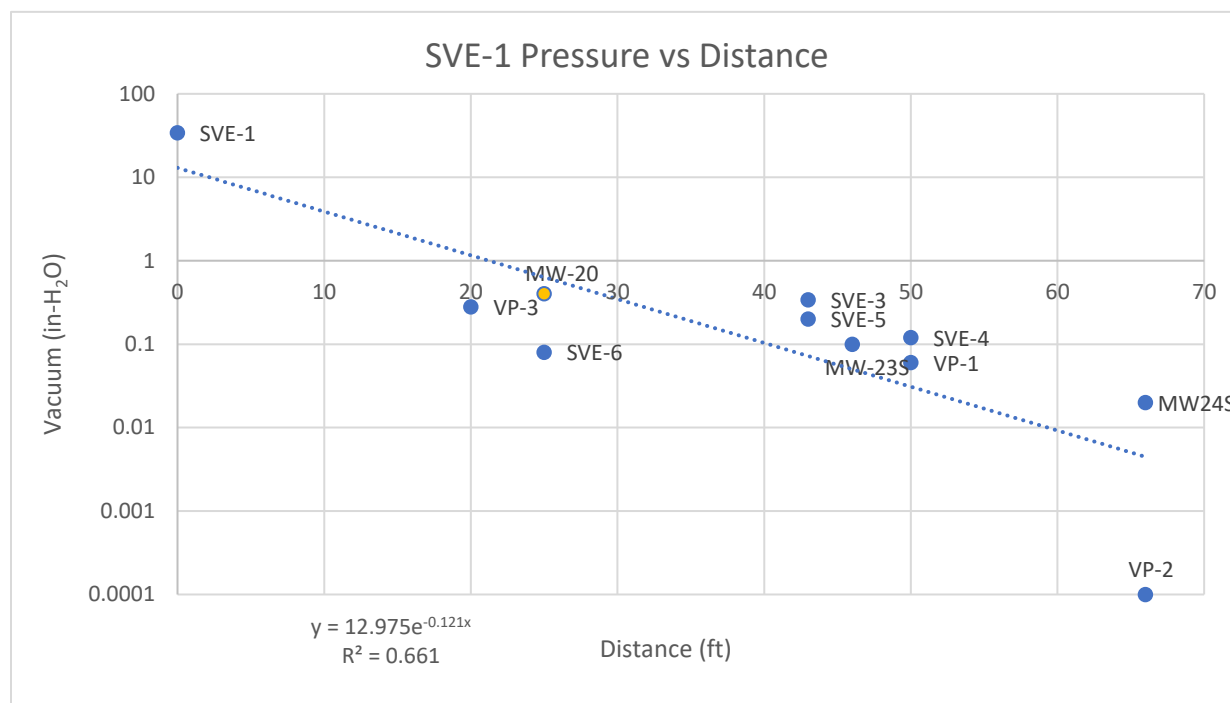


Table 4.2.2 below summarizes the ROI for each of the SVE extraction points at observation wells where the pressures were greater than or equal to 0.1 in-H₂O.

Table 4.2.2 SVE Well Radius of Influence (ROI)

SVE Well ID	SVE Well Pressure (in-H ₂ O)	Air Flow (scfm)	Observation Wells ≥0.1 in-H ₂ O	Maximum Distance from SVE Well Tested ≥0.1 in-H ₂ O
SVE-1	-34	38.6	VP-3, MW-20, SVE-3, SVE-5, MW-23S, SVE-4	50-ft
SVE-2	-34	22.8	SVE-1, SVE-3, MW-20, SVE-4, SVE-5	50-ft
SVE-3	-36	18.70	SVE-4, MW-20, MW-23S, SVE-1, SVE-5	64-ft
SVE-4	-13	37.5	SVE-3, SVE-5, MW-20, MW-23S, SVE-1, VP-1	65-ft
SVE-5	-16	38.69	MW-20, SVE-4, MW-23S, MW-24S, VP-3, VP-1, SVE-1, SVE-3	44-ft
SVE-6	-14	35.81	VP-3, SVE-1, MW-20, MW-23S, VP-1, SVE-4, SVE-3	50-ft

The ROI for each of the SVE extraction points was mapped to detail the SVE system coverage over the impacted soil and groundwater (based on the Bristol 2017 site investigation reports. Figure 4 (SVE Radius of Influence Map) illustrates the extent of ROI in relationship to the soil and groundwater plume identified at both Tower and Sundberg properties.

4.3 AS System Performance

AS system testing began with calculating the pressure needed to overcome the force of hydraulic head at the shallow and deep sparge points. A conversion factor of 1 pound per square inch (psi) of blower pressure for every 2.31 feet of hydraulic head was used to calculate the initial blower pressure for the air sparge well points. These calculations yielded an initial sparge pressure of 6.5 psi for the shallow AS wells and 22.5 psi for the deep AS wells.

The duration of the AS-only test was short relative to the SVE step testing and completed initially using air sparge points AS-2 and AS-4. This test was initiated at 08:10 and completed at 08:50. The total AS system was operated by itself for less than 60 minutes. Air sparge test duration and number of air sparge wells tested was limited to prevent/minimize mobilization of groundwater plume volatile contaminants away from the prescribed treatment area.

AS system performance was evaluated based on the response of these two key parameters: dissolved oxygen (DO) and static water level measurements and, to a lesser extent, pressure measurements at the vapor point locations. The following sections discuss the performance of the AS System.

4.3.1 Radius of Influence (ROI)

Monitoring wells MW-20 and MW-20D centered within the source area of the groundwater plume and the AS/SVE system array were observation points for DO and changing water levels while pumping air to all six sparge points. DO, measured in milligrams per liter (mg/l), increased in concentration from 0.51 mg/l to as high as 2.06 mg/l during the initial AS system test. Rising water level measurements in shallow well MW-20 were also observed indicating that sparge air denoting slight upwelling of the static water level as air was introduced into the groundwater contaminant plume.

The effects of the AS system were not evident in the slightly deeper monitoring well MW-20D. Concentration of DO decreased over time as the sparge air was introduced into the contaminant plume. This may be more of a result of the length of the AS test rather than the ability of sparged air to oxygenate the water.

Sparge points AS-4 (deep) and AS-5 (shallow) are within 12-feet of monitoring well MW-20. From the DO concentrations observed at MW-20, the sparged air from the system was observed to add oxygen to the contaminant plume at depth. Increases in overall subsurface air pressure were also evident at vapor points VP-1, VP2, and VP-3. Pressure at monitoring points VP-1, VP-2, and VP-3, measured in in-H₂O, were 0.06, 0.1, and 0.04 respectively.

4.4 AS/SVE System Performance

System performance pressure and flow were evaluated at the six AS and SVE sparge/vapor extraction points as well as at the three vapor points during AS/SVE total system operation. Uncapped groundwater monitoring wells were used to collect DO and water level data while the system effluent gas was monitored in the field at the pre- and post-GAC sample ports. AS/SVE system performance is discussed in the following sections below.

4.4.1 Capture Effectiveness of SVE Wells to Sparged Air

SVE system capture of sparged air was evident in the change in DO concentrations observed at MW-20 during the full system test. At the initial AS system start up, DO concentrations increased at MW-20 from 0.51 mg/l to over 2 mg/l. Once the complete AS/SVE system was running, DO concentrations decreased to below the baseline concentration of 0.51 mg/l.

An observed increase in the percentage of oxygen (O₂) measured in the field at the pre-GAC sample location may provide a secondary level of evidence that the SVE system was capturing sparged air while the total system was operational. Table 4.4.1 presents the results of the field DO concentrations as well as the percent O₂ measured pre-GAC during the total AS/SVE system test.

Table 4.4.1 MW-20 DO Concentrations/Pre-GAC O₂ % Measurements

MW-20									
Baseline		AS System				AS/SVE (Total System)			
Clock Time	0	10:40	10:50	10:52	11:00	13:15	13:30	13:45	14:00
DO (mg/L)	0.51	1.2	1.71	2.06	1.33	0.47	0.46	0.46	0.45
		AS/SVE (Total System)							
Clock Time		11:35	12:05	12:30	13:00	13:15	13:30	13:45	14:00
O ₂ % (pre-GAC)		14.9	14.9	15.4	15.9	16.1	16.2	16.3	16.5

4.4.2 Water Table Mounding

Water level measurements were collected using industry standard water level meters multiple times during the course of the AS/SVE pilot study field work. Pressure transducers (ONSET HOBO brand units) were also used to provide data on changing downhole pressure (normalized to a baseline water table elevation) measurement over time. The advantage of using the HOBO transducers was that pressure-normalized water table elevations could be measured at SVE or monitoring well locations that were sealed in order to record changes in pressure during SVE step tests. A major disadvantage of the pressure transducers was their sensitivity to pressure changes that were inherently part of the AS/SVE system pilot test.

Table 4.4.2 below summarizes the water level measurements collected by hand at water table well MW-20 in the center of the AS/SVE system array as well as monitoring wells outside of the AS/SVE system array while the total system was operational. With the exception of one perimeter water level measurement, the water level meter probe was continuously monitoring the water level at water table well MW-20. (During the total system test sparge points, SVE wells, and some of the perimeter monitoring well points were capped with valves that were used for measuring changes in pressure during the test.) The scale values on the water level measuring tape were re-set at 0.1-ft increments (as the water table rose) with the alarm providing an audio signal for recording each new increment.

The baseline water level measurement at water table well MW-20 was 7.56 ft below the well top of casing with its maximum upward deflection of 7.10 ft below the well top of casing for a maximum upward deflection of 0.46 ft. The AS/SVE total system test did not result in a significant mounding of the water table that would affect the performance of the AS/SVE system design.

Table 4.4.2 AS/SVE Total System Test Water Level Data at Monitoring Wells

Water Table Elevations During AS/SVE Total System Operation							
Well Location/Water Level Measurements							
Clock Time	MW-20	MW-21D	MW-21M	MW-23S	MW-23D	MW-24S	MW-24D
Baseline	7.56	7.71	7.59	7.61	7.57	7.67	7.51
8:45	7.4	---	---	---	---	---	---
10:20	7.4	---	---	---	---	---	---
10:25	7.3	---	---	---	---	---	---
10:30	7.3	---	---	---	---	---	---
10:35	---	7.7	7.58	7.53	7.57	7.64	7.76
10:52	7.2	---	---	---	---	---	---
11:33	7.2	---	---	---	---	---	---
12:00	7.1	---	---	---	---	---	---
Difference	0.46	0.01	0.01	0.08	0	0.03	-0.25

Water level measurements in feet below monitoring well top of casing --- = No field measurements collected.

Pressure transducer data was collected from SVE-1, SVE-2, SVE-3, SVE-5, and SVE-6. These extraction points were connected to the AS/SVE system so collection of water level measurements during the total system test was not possible. HOBO transducers were also placed in MW-20 and MW-20D. A barometric compensation transducer was kept aboveground with its data used for diurnal pressure corrections due to changing atmospheric pressure.

Figure 5 (Pressure Plots During Air Sparge Test) depicts the pressure responses (normalized to static water levels) for extraction points SVE-1, SVE-2, SVE-3, SVE-5 and SVE-6 during the air sparge only testing at sparge points AS-2 and AS-4. The clock time interval for the air sparge test for AS-2/AS-4 was 08:10 to 08:50.

Transducer pressure was relatively constant between the start of the test at 08:10 until approximately 08:32. At 08:32, a steady increase in pressure was observed at the SVE wells monitored with transducers. Increasing pressure may be the result of a mounding of the water table or simply a change of total pressure as a result of the introduction of sparged air from AS-2/AS-4. In either case the pressure differential "water table mounding" data shows that the upward deflection is less than 0.5 ft for this portion of the test.

The HOBO transducer pressure response data obtained during the total AS/SVE system operation is provided in Figure 6 (Pressure Plots During Total System Operation). Total AS/SVE system start-up was at 10:20 and initially ran for approximately 50 minutes until the system was shut down to adjust for air sparge over pressure. Once the adjustments were made, the system was restarted at 11:00 and then ran continually until 14:00.

From the restart of the system at 11:00 until approximately 12:15 there was an increase in pressure observed at the extraction wells monitored with transducers. There was evidence of background noise observed in the pressure responses at SVE-1, SVE-5, and SVE-6 or that the system was working toward a state of equilibrium. These three extraction points appeared to have nearly identical overall response signatures even though the magnitude of the responses were substantially different. At approximately 12:20, the pressure response for all five SVE wells monitored with the transducers appeared to stabilize for the duration of the test relative to their observed initial start-up responses.

As with the short AS only test, the pressure differential/"water table mounding" as recorded during AS/SVE total system operation was less than 0.5 ft at SVE-5 where the greatest pressure changes over time were observed. The downhole pressure transducers confirm that the AS/SVE total system operation did not result in a significant mounding of the water table that would affect the performance of the AS/SVE system design.

The pressure-depth responses were not plotted for monitoring wells MW-20 and MW-20D because downhole instruments used to measure DO were inserted and removed from these locations during the AS/SVE total system testing. As such, the responses were very noisy with response signatures that did not remotely match that of the SVE pressure-depth responses.

4.4.3 Potential for Iron Fouling

According to an EPA document entitled How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites- Chapter VII Air Sparging (publication EPA 510-B-17-003; October 2017), concentrations of dissolved iron in groundwater can reduce the permeability of the saturated zone during air sparge operations. In addition, dissolved iron in the presence of oxygen (near the sparge point) can precipitate out and foul the sparge well screens.

The EPA publication provides a range of dissolved iron concentrations that may impact air sparge effectiveness. Table 4.4.3 below summarizes the range of acceptable, marginal, and unacceptable dissolved iron concentrations for effective air sparge system operation along with the dissolved iron concentrations from the November 2020 groundwater sample event completed by Bristol.

Table 4.4.3 Monitoring Well Screened Interval and Dissolved Iron Concentrations

Air Sparging Effective Concentration Ranges				Monitoring Well			
Parameter	Acceptable	Marginal	Unacceptable	MW-20	MW-20D	MW-21D	MW-21M
Dissolved Iron (mg/l)	< 10	≥10, ≤20	>20	16	6.87	4.57	19.8
Screened Interval	---	---	---	5-15	20-25	35-40	5-15
Monitoring Well							
Parameter	Acceptable	Marginal	Unacceptable	MW-23D	MW-23S	MW-24D	MW-24S
Dissolved Iron (mg/l)	< 10	≥10, ≤20	>20	<0.25	6.93	6.05	7.09
Screened Interval	---	---	---	40-50	5-15	35-45	5-15

mg/l = milligrams per liter.

Monitoring well screened interval in feet below land surface.

= Dissolved iron concentrations reported in the marginal range from recent Bristol ground water sampling event.

1

Dissolved iron detected in groundwater samples collected from shallow monitoring wells MW-20 and MW-21 at concentrations of 16 mg/l and 19.8 mg/l respectively fall within the marginal range for air sparge well effectiveness. Monitoring wells MW-20 and MW-21M are water table wells; their well screened intervals intersect the shallow water table at the property.

Shallow air sparge wells (screened from 20- to 22-ft bgs) and deep air sparge wells (screened between 56- to 58-ft bgs) are below the groundwater horizons that exhibit dissolved iron in the marginal range for air sparge effectiveness. Dissolved iron concentrations collected from monitoring wells MW-20D, MW-21D, MW-23D, MW-23S, MW-24D, and MW-24S were all below the 10 mg/l benchmark concentration for air sparging effectiveness.

Based on the most recent groundwater analytical results, dissolved iron is located higher up in the water column and not directly in contact with the deeper air sparge well screened intervals.

4.4.4 GAC System Performance

Volatile organic vapors extracted from the subsurface via the AS/SVE system were passed through granulated activated charcoal (GAC) filters prior to discharge to the atmosphere. As described, the GAS filter system consisted of two 55-gallon open-top steel drums filled

with GAC. The drums were fitted with PVC couplings for use with camlock hose connectors. The drums were connected in series and the second drum was fitted with a 6-ft vent for discharge to the atmosphere. Sample ports were located on the inlet pipe for pre-GAC metering and on the vent stack for post-GAC monitoring.

SWI personnel monitored pre- and post-GAC hydrogen sulfide (H₂S), methane (CH₄), carbon monoxide (CO), and percent oxygen (O₂) with a (Ventis MX-4) 4-gas meter at fixed time intervals. Total volatiles were measured using a photoionization detector (PID) calibrated to an isobutylene gas standard. This measures total volatile vapors in parts per million instrument units (ppm IUs) as benzene equivalents (based on the ionization potential of the compound). Pre- and post-GAC sampling as well as pressure measurements at SVE, vapor points, and monitoring wells were completed and recorded daily during the AS/SVE pilot test.

Table 1 (Tower Standard AS/SVE Pre-/Post- GAC Effluent Gas Measurements) contains the pre- and post-GAC field measurements as well as the volume of volatile organic fraction measured in PID IU benzene equivalents captured by GAC filtration prior to atmospheric discharge. At a minimum, the GAC system removed 99.7% of the volatile fraction of SVE system extracted vapors before being discharged to the atmosphere. Pre-GAC PID concentrations were also used to provide an empirical assessment of the performance of each SVE well, the entire SVE system operation and the AS/SVE system as a whole.

Pre- and post GAC monitoring results from summa canister sampling are provided in the Bristol Pilot Study Report. Summa canister sampling results confirmed that the GAC system removed on average 99.9% of volatiles extracted by the SVE system, before discharge to the atmosphere, with the minimum percent removed being 98.2%. This is evidence of some contaminant break through. An evaluation of chemical compounds that were detected in post-GAC summa canister samples will be completed as part of the full AS/SVE system design.

5 MASS CONTAMINANT RECOVERY

5.1 SVE System Mass Contaminant Recovery

SVE system effluent gas was monitored prior to entering the GAC vapor filter for each of the step tests performed on the SVE system. Table 5.1 summarizes the maximum PID value recorded for each step test at every SVE vapor extraction point. A more comprehensive table including the time intervals and the results of the of methane, carbon monoxide, hydrogen sulfide, and oxygen monitoring pre- and post GAC is provided in Table 3 (Pre-Post- GAC Field Measurements).

Table 5.1 SVE System Step Test System Effluent Gas Monitoring

SVE Step Test- Effluent Gas Monitoring Results				
SVE	Step 1 (in-H ₂ O)	PID (ppm IU)	Step 2 (in-H ₂ O)	PID (ppm IU)
SVE-1	10	730	34	1,723
SVE-2	---	---	34	665
SVE-3	---	---	36	980
SVE-4	10	138	13	168
SVE-5	10	163	34	475
SVE-6	10	712	14	933

"--- = Could not establish sustainable air flow at lower pressures

Based on pre-GAC monitoring alone, it appears that significant concentrations of volatile organic vapors associated with gasoline petroleum hydrocarbons were evacuated from the subsurface by the SVE system. There is a direct relationship between air flow and the concentration of benzene equivalents measured in the SVE system effluent gas.

Concentrations of effluent gas increased from 17.9% to nearly 66% from step 1 to step 2 at extraction wells SVE-1, SVE-4, SVE-5, and SVE-6.

Pre-GAC monitoring was more qualitative than quantitative in that the PID response was a measure of relative effluent gas total VOC concentrations. Effluent gas monitoring was a field test to ensure that the SVE system was capturing VOCs from the subsurface. Pre-GAC PID monitoring was also used to determine "steady state" conditions. Additional sampling and verification was completed in order to validate the empirical data presented in this table. The Summa canister sample results presented below were used to verify and quantify the VOC compounds that made up the AS/SVE effluent gas observed from the field data presented above.

5.1.1 SVE Summa Canister Samples

Suma canisters were used to collect effluent gas samples from SVE extraction well pairs after the entire SVE system was fully operational. Prior to summa canister sampling, the fully operational SVE system ran for approximately 45-minutes until an observed "steady state" (no significant change in PID measured values) was achieved. The average concentration of pre-GAC SVE system effluent gas was 778 ppm IU with a range of 774-780 ppm IUs.

SVE well pairs were sampled while the remaining SVE wells continued to operate. Summa canisters collected during the partial SVE system operation were identified as the "A" effluent gas samples.

Table 5.1.1 below summarizes the results of the summa canister sampling at each SVE extraction point while the remaining four SVE wells were in operation.

Table 5.1.1 SVE System Effluent Gas Sample A

Summa Cannister Sample Collection After SVE and AS/SVE Operation											
Major Gasoline Volatile Organic Compounds											
Sample A (SVE only)											
Sample Location	Predominant Gasoline Compounds										Broad Spectrum Gasoline Compounds
SVE	Benzene	Ethylbenzene	Toluene	Xylenes (total)	MTBE	1,2,4-TMB	1,3,5-TMB	n-Heptane	n-Hexane	Cyclohexane	THC as Gasoline
SVE-1	29,800	61,400	136,000	160,800	239	1,670	971	1,850,000	613,000	1,600,000	21,900,000
SVE-2	1,660	7,810	1,840	43,390	955	1,390	1,460	62,100	23,800	59,200	1,840,000
SVE-3	5,230	84,100	19,100	276,500	239	12,100	8,250	539,000	146,000	547,000	13,400,000
SVE-4	2,400	106,000	53,600	398,300	253	4,710	4,100	44,300	6,810	22,800	2,360,000
SVE-5	1,350	83,300	28,500	361,300	248	8,550	6,520	20,200	4,880	14,600	1,610,000
SVE-6	4,110	62,800	14,900	177,600	248	12,200	9,430	109,000	23,100	71,100	3,640,000
GAC IN	9,440	117,000	62,400	495,000	292	81,100	31,100	544,000	88,900	254,000	8,290,000
Average	7,713	74,630	45,191	273,270	353	17,389	8,833	452,657	129,499	366,957	7,577,143

MTBE = Methyl tert-butyl ether

TMB = Trimethylbenzene

GAC = Granulated Activated Carbon Canister

PID = Photoionization detector

5.2 AS/SVE System Mass Contaminant Recovery

Pre-GAC total AS/SVE system effluent gas monitoring was also completed once the entire AS/SVE system was fully operational (3-shallow and 3-deep air sparge points and 6-vapor extraction points). The complete AS/SVE system ran continuously for approximately 2 ½-hours; “steady state” was achieved at 60 minutes when there was no significant change in the pre-GAC effluent gas PID measured concentrations. The average concentration of pre-GAC total AS/SVE system effluent gas was 1,124 ppm IU with a range of 1,123 – 1,159 ppm IUs. The average concentration of the pre-GAC for the total AS/SVE system increased by 31% over the pre-GAC SVE system only effluent gas concentrations measured by the PID.

5.2.1 AS/SVE Summa Canister Samples

Once the “steady state” had been observed, summa canisters were used to collect AS/SVE system vapors from each of the SVE extraction well locations. Table 5.2.1 below summarizes the results of the summa canister sampling results for the total AS/SVE system. Summa canister gas samples for the total AS/SVE system are identified as the “B” effluent gas samples.

Table 5.2.1 Total AS/SVE System Effluent Gas Sample B

Summa Cannister Sample Collection After SVE and AS/SVE Operation											
Major Gasoline Volatile Organic Compounds											
Sample B (SVE and Air Sparging)											
Sample Location	Predominant Gasoline Compounds										Broad Spectrum Gasoline Compounds
	Benzene	Ethylbenzene	Toluene	Xylenes (total)	MTBE	1,2,4-TMB	1,3,5-TMB	n-Heptane	n-Hexane	Cyclohexane	THC as Gasoline
SVE											
SVE-1	16,900	18,300	58,800	47,250	465	751	766	268,000	172,000	520	6,820,000
SVE-2	1,240	2,930	576	18,720	0	550	458	30,500	17,500	12,000	760,000
SVE-3	2,990	64,600	41,800	199,900	47	10,800	5,550	79,300	43,000	52	3,400,000
SVE-4	23	1,620	2,310	7,340	23	312	210	81,000	1,330,000	119,000	3,660,000
SVE-5	128,000	38,700	87,400	108,300	465	9,620	5,740	389,000	3,670,000	641,000	18,400,000
SVE-6	33,500	42,500	77,600	113,300	12	5,250	3,170	135,000	255,000	13	4,250,000
GAC IN	81,100	94,900	145,000	359,400	23	23,100	11,300	429,000	1,250,000	26	13,900,000
Average	37,679	37,650	59,069	122,030	148	7,198	3,885	201,686	962,500	110,373	7,312,857

MTBE = Methyl tert-butyl ether

TMB = Trimethylbenzene

GAC = Granulated Activated Carbon Canister

PID = Photoionization detector

Concentrations of benzene and toluene increased when the sparged air was applied to the total system while the other petroleum volatile organic constituents concentrations decreased. Lower molecular weight compounds like benzene and toluene are more easily volatilized compared to their heavier gasoline fuel component counterparts.

5.3 AS/SVE System Zone Testing

In the field, it was suspected that there were preferential flow paths for the movement of air (and vapors) in the subsurface. This was especially evident in the vicinity of extraction wells SVE-2 and to a lesser extent SVE-3. The pressure response of SVE-2 when the vacuum was applied to neighboring extraction points SVE-1 and SVE-5 was non-existent. SVE-2s pressure response when SVE-6 was isolated for pressure testing was non-detect.

Conversely, vapor extraction wells SVE-1, SVE-5, and SVE-6 each had measured responses when pressure was applied while testing SVE-2. Clearly, there are differences in the behavior of air (vapor) flow in the subsurface in the vicinity of the pilot study that were not predicted based on soil profiles from recent drilling.

In order to determine if these pressure anomalies would impact the operation of the AS/SVE system, zone testing was completed as an empirical measure of AS/SVE performance or system failure. Zone testing consisted of shutting down the air flow to specific SVE well(s) and then measuring the pre-GAC effluent concentrations to see if there

were substantial differences in the measured PID concentrations. Table 5.3 below summarizes the SVE wells that were shut down, the SVE wells that were left on-line and the observed PID concentrations measured pre-GAC.

Table 5.3 AS/SVE Zone Testing

AS/SVE Zone Test			
Time	SVE Wells Shut off	SVE Wells On	Pre-GAC PID ppm IU
15:05 15:15	SVE 1,2,3	SVE 4,5,6	1270
15:15 15:25	SVE 1,5,6	SVE 2,3,4	830
15:25 15:38	SVE 1, 4, 5, 6	SVE 2,3	880
15:38 15:48	SVE 1,2,3,4	SVE 5,6	1283
15:48 15:54	SVE 1,2,3,4,6	SVE 5	1114

Note that the duration of the zone test while fairly short yielded beneficial information that will be taken into consideration for the design of the full-scale AS/SVE system. SVE wells SVE-2, SVE-3, and SVE-4 yielded approximately 30% lower pre-GAC effluent concentrations than SVE wells VSE-4, VSE-5, and SVE-6. By itself, extraction well SVE-5 contributed over 1,110 PID ppm IU to the total mass of the effluent concentration.

6 AS/SVE REMOVAL RATES

Mass removal rates were calculated for the pre-GAC total AS/SVE system effluent as well as for the Effluent Sample A (SVE only) and Effluent Sample B (total AS/SVE) summa canister results.

6.1 Summa Canister Mass Removal Rates

Summa canister analytical results were used to quantify the AS/SVE system's potential to reduce the total mass of VOC in the subsurface soil and groundwater at the property. Concentrations of VOCs removed during the SVE system only (Sample A) and with the total AS/SVB system (Sample B) were calculated for a number of gasoline fraction components. Two chlorinated VOC compounds (tetrachloroethene (PCE) and trichloroethene (TCE) were also captured in the summa can vapor analysis. Mass removal rates calculated for summa cannister sampling event A (Sample A) and summa cannister sample event B (Sample B) are

provided in Table 6.2 below. Predictions of contaminant mass removal rates for each of these sample events is summarized in Table 6.2 below.

Table 6.2 Mass Removal Based on Summa Canister Data

Mass Removal Summary Table from Summa Canister Results				
Compound	Sample A (kg/hr)	Sample B (kg/hr)	Sample A (lbs/hr)	Sample B (lbs/hr)
Benzene	0.00276	0.01031	0.00608	0.02272
Ethylbenzene	0.02241	0.01096	0.04940	0.02417
Methyl-tert-butyl ether	0.00012	0.00005	0.00027	0.00010
Naphthalene	0.00175	0.00036	0.00385	0.00080
Toluene	0.01792	0.02114	0.03950	0.04660
1,2,4-Trimethylbenzene	0.00163	0.00098	0.00360	0.00215
1,3,5-Trimethylbenzene	0.00127	0.00058	0.00280	0.00128
Xylene (Total)	0.07613	0.03110	0.16785	0.06857
Cyclohexane	0.11226	0.03663	0.24749	0.08074
n-Heptane	0.13676	0.06774	0.30151	0.14935
n-Hexane	0.04014	0.27099	0.08850	0.59743
THC as Gas	2.35051	2.62091	5.18198	5.77811
Tetrachloroethene (PCE)	0.00023	0.00011	0.00051	0.00024
Trichloroethene (TCE)	0.00020	0.00007	0.00043	0.00016

7 CONCLUSIONS

The AS/SVE system is technology that is viable for the removal of gasoline fraction volatile organic compounds from the subsurface soil and groundwater at the Sundberg property. It has been demonstrated that a significant mass of gasoline fraction VOCs can be removed using soil vapor extraction augmented with sparged air. This is evident by the concentrations of Total Hydrocarbons (THC) as gasoline detected in the summa cannisters for each SVE well and post-GAC sampling.

ROIs observed at the SVE well locations provide overlapping coverage of the SVE extracted air (vapors) centered on monitoring wells MW-20 and MW-20D that have exhibited the highest concentrations of petroleum volatile organic constituents in groundwater samples collected. The radius of influence for the SVE wells was based on a 0.1 in-H₂O pressure response in the adjacent groundwater monitoring wells, SVE wells and vapor monitoring points. For the AS/SVE system as designed, the range of ROI distances was from 44- to 65-ft from the SVE extraction points.

Mounding of the shallow water table as a result of applying pressure to shallow vapor extraction points as well as introducing sparged air into the saturated zone did not occur and as a result did not impact the operation of the AS/SVE system. The largest upward

deflection measured at water table monitoring well MW-20 during the AS/SVE total system operation was 0.46 ft. Pressure transducer data obtained during the AS/SVE total system testing confirmed that the observed change in pressure normalized to the water table elevations did not rise above the soil vapor extraction well screened intervals.

Pre-GAC monitoring of the AS/SVE system effluent gas was a qualitative indicator of system performance. Based on the initial pre-GAC field monitoring, the SVE system alone was effective in capturing gasoline fraction VOCs in the subsurface soil and groundwater. The addition of sparged air increased the amount of VOC vapors in the pre-GAC system effluent measured by the PID.

Six VOCs were identified in the post-GAC summa cannister sampling. A re-evaluation of the AS/SVE effluent capture system is recommended based on the air discharge limits of the compounds and the technology available for vapor effluent treatment.

Sparged air increased the concentration of dissolved oxygen at monitoring well MW-20, 12-feet away from the closest air sparge point. This confirmed that sparged air was mobile in the subsurface. The SVE system was effective in capturing sparged air. This was evident by the decreasing DO concentrations also at MW-20 and an increase in the percent O₂ observed in the pre-GAC AS/SVE system effluent.

Pressure changes were observed at vapor point locations VP-1, VP-2, and VP-3 during the AS/SVE total system operation. The pressure changes fluctuated between positive and negative pressure. It is anticipated that the total AS/SVE system was approaching an equilibrium condition during the AS/SVE total system testing. An influence of the total AS/SVE system was observed outside the AS/SVE system array at these locations.

While the pressure response between SVE-1 and SVE-2 was anomalous and the well integrity is in question, SVE-2 was successful in removing THC as gasoline and other VOCs from the subsurface.

8 REFERENCES

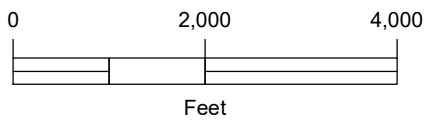
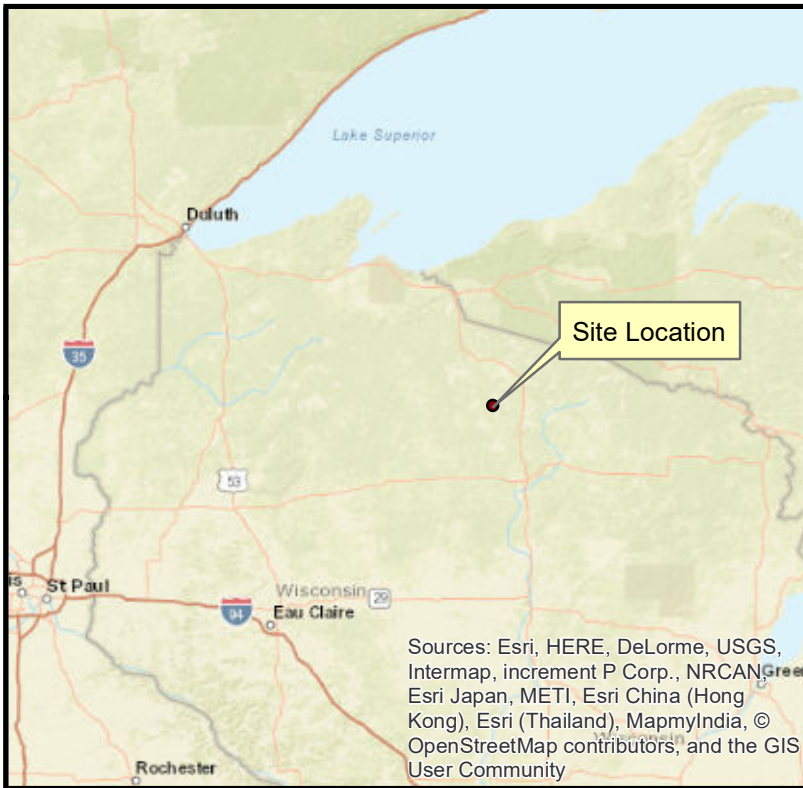
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Figures

FIGURES



FIGURES



Tower Standard LUST Site
Lac Du Flambeau, Wisconsin

Site Location Map

May 2020

105161-001



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Figure 1

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State Highway 70

Bait Shop
(Former Service Station)

Legend

- VOCs in Soil > 500 ug/kg Contour
- Property Line

Well Type

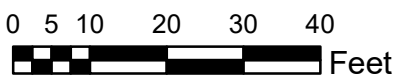
- Air Sparge Well
- Monitoring Well
- Soil Vapor Extraction
- Vapor Point

A to A'
(See Figure 3 for Cross Section)



Notes:

VOC data from Bristol 2017 report.



Tower Standard
AS/SVE

**AS/SVE/MONITORING WELL
AND VAPOR POINT LOCATION MAP**

February 2021 105161-003

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Figure 2

Image provided by University of Alaska Fairbanks Geographic Information
Network of Alaska and the Alaska Statewide Digital Mapping initiative:
www.gina.alaska.edu & www.alaskamapped.org.

State Highway 70

Bait Shop
(Former Service Station)

SVE-1 ROI

SVE-6 ROI

SVE-3 ROI

SVE-2 ROI

SVE-5 ROI

SVE-4 ROI

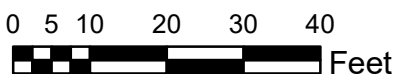
- MW VP3
- MW-21D
- MW-21M
- SVE-6
- MW VP1
- MW VP2
- MW-24S
- MW-24D
- MW-23S
- MW-23D
- SVE-1
- AS-1
- AS-2
- AS-3
- AS-4
- AS-5
- AS-6
- MW-20 D
- MW-20
- SVE-2
- SVE-3
- SVE-4
- SVE-5

Legend

- VOCs in Soil > 500 ug/kg Contour
- Radius of Influence
- Property Line
- Well Type**
 - Air Sparge Well
 - Monitoring Well
 - Soil Vapor Extraction
 - Vapor Point



Notes:
ROI - Radius of Influence
VOC data from Bristol 2017 report.



Tower Standard
AS/SVE

**SITE MAP
RADIUS OF INFLUENCE**

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